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Operators'

1987 Seminar

Alberta
ENVIRONMENT

1987 OPERATORS SEMINAR

PRESENTATIONS

MADE AT THE 1987

ALBERTA OPERATORS SEMINAR

BANFF PARK LODGE

March 11,12, 13, and 14, 1987

INTRODUCTION

The Alberta Water and Wastewater Operators' Seminar is an annual updating and general technical information program co-sponsored by the Alberta Water and Wastewater Association, the Western Canada Water and Wastewater Association, and Alberta Environment. The Seminar is designed to be of interest to treatment plant operators, distribution and collection system operators, and village and town formen and superintendents. A wide variety of topics relating to water treatment, water distribution, wastewater collection, and wastewater treatment are discussed. Displays set up by equipment and product suppliers provide an opportunity for operators to view the latest in treatment equipment.

This publication is a collection of the presentations made at the Seminar in 1987.

The Pollution Control Division of Alberta Environment, as well as the co-sponsoring organizations, assumes no responsibility for opinions or statements of facts expressed by contributors. Speakers' opinions do not necessarily represent official policy.

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LIST OF SPEAKERS

Glen Horne, C.E.T.
President
Camenex Control Systems Ltd.
Edmonton

Doug V. Rhodes
Western Regional Manager
Muesco Canada
Richmond, B.C.

Bob Spon
Vice President - Sales
Kjell Water Consultants Inc.
Wisconsin

Dr. C. Guarnaschelli, President
Associated R & D Engineering
Edmonton

K. G. Elstone
Superintendent
Gold Bar Wastewater Treatment Plant
Edmonton

Don Beith, President
Carrying Industries of Alberta Ltd.
Edmonton

Chuck Bullen
Western Representative
National Silicates Ltd.
West Vancouver, B.C.

W. T. (Wilf) Crane
President
BCA Industrial Controls Ltd.
Surrey, B.C.

Poul Wesch
Sales Manager
WSH Laboratories Ltd.
Calgary

Brian Herner
Vice President, Water Systems
Zenon Environmental Inc.
Burlington, Ontario

Jim Yule, President
Colony-Viking Services Ltd.
St. Paul

M. T. Yakemchuk, P.Eng.
Manager, Pipe Division
Colsolidated Concrete
Edmonton

Karl Welz
Water Treatment Plant Operator
E. L. Smith Water Treatment Plant
Edmonton

Andy Maguire
Water Treatment Plant Operator
Rossdale Water Treatment Plant
Edmonton

Gavin Morcom
Product Manager, Municipal Products
Neptune Meters
Toronto

Jim Gratz
Utilities Supervixor
Strathmore

J. B. Hambley, P.Eng.
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M. S. McClure, P.Eng.
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Municipal Engineering Branch
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Edmonton

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SCALE AND CORROSION INHIBITORS

Robert S. Spon
Kjell Water Consultants Inc.

Scale and corrosion inhibitors classified as "polyphosphate" were first recognized by a U.S. patent in 1887 covering the use of trisodium phosphate to prevent boiler scale. However, it wasn't until half a century later that sodium phosphates were introduced as synthetic cleaning agents in place of soap. Sodium Tripolyphosphate was used in the first commercially produced detergent by Proctor & Gamble, called TIDE. The development of the Langelier Saturation Index was closely followed in the late 1930's by a "threshold treatment" process which called for the addition of a few parts per million of sodium hexametaphosphate to water for control of the precipitation of calcium carbonate. This report by O. Rice and G. B. Hatch was expanded as they continued to emphasize the usefulness of "thresholding" to minimize corrosion and red water. It is from this initial basis that today we have been able to formulate and incorporate many of the properties of sequestration, dispersion, and buffering into a product that can withstand the many demands that occur throughout a potable water distribution system.

To briefly describe the different phosphates that are available for use as water conditioners, let me first divide them into two basic categories: orthophosphates and condensed phosphates.

The orthophosphates are the simplest sodiumphosphate salts, such as mono, di, and trisodium phosphate. These forms are produced by combining orthophosphoric acid (H_3PO_4) with soda ash (Na_2CO_3) and sodiumhydroxide (NaOH). These orthophosphates are then fused through a heating process to form "condensed phosphate", which can be of either the crystalline or glassy form.

The crystalline sodium tripolyphosphate and glassy sodium hexametaphosphate are two easily recognizable products widely used in the water treatment industry. The next steps of formulation under various degrees of time and temperature lead to the specialty blends of proprietary liquid compounds. These condensed phosphates contain a mixture of phosphate oxygen chains of various lengths. It is the additional step of forming linear chain and polymerized phosphates from the basic building blocks of generic polyphosphates that leads to the breakpoint of success in the somewhat marginal results of some existing phosphate treatment programs.

Phosphates used in potable water supply systems are known to effectively reduce tuberculation in distribution lines, minimize red and black water caused by high iron and manganese or the by-products of an aggressive water.

These corrosion problems are extensive in old cast iron main systems. Estimates have placed losses in supply distribution systems at $700 million each year, not including additional costs for services and inside plumbing. Corrosion of these ferrous metal pipes unfortunately results in the formation of iron oxide by-products which occupy a greater volume of space than the metal loss from the pipe wall. The accumulation of this tuberculation reduces the flow rate and overall carrying capacity of lines. One inch of scale on an eight inch water main reduces flow capacity by more than 50 percent. Increased electrical pumping costs and fire insurance ratings reflect this unfortunate consequence of even a minor scale or corrosion problem. These deposits are also quite evident through excessive replacement of hot water systems, where the reaction rate of scale formation is accelerated. In addition to these extreme replacement costs, taste, colour, and odour from iron and copper corrosion (red and blue-green staining) are potential sources of consumer complaints.

Through use of polymerized phosphate, inhibition of these problems is both efficient and effective. The example of the scale formation or the corrosion rates in hot water systems can be evidence of how the phosphate treatment is performing in the entire system. Generally, higher temperatures cause more rapid rates in chemical reactions and usually reduce the solubility of minerals, as seen by calcium carbonate scale formation in heat transfer surfaces. Except for cases where the alkalinity of the water is less than 50 ppm, the solubility product for $CaCO_3$ decreases. This is due to the buffering concentration and its hindrance of the temperature effect on pH.

These basic principles can be correlated to the characteristics of phosphates in sequestering iron and conditioning the hardness while under the extreme condition of hot water tank temperatures of 130 to 160 degrees Fahrenheit. By concentrating on the simple activities in a hot water heater, months of testing and theorizing can be saved determining the effectiveness of the phosphate program within the entire distribution system. If a phosphate can stand up to the stringent requirements in the hot water system, we can be very optimistic about satisfying the water utility and the water user.

After a complete water analysis has been performed for the specific components, (iron, manganese, silica, alkalinity, hardness [calcium, magnesium] and pH) the chemical distributor and supplier of the phosphate treatment should verify and dose the product based on the water quality parameters. After the background tests and standards are compiled, the phosphate can now be monitored to show the overall performance. Test data from field analysis for ferrous and ferric iron, phosphate (PO_4 and total), manganese, turbidity, free and total chlorine are all valuable pieces of information. Various sites in the system can be determined for control and experimental samples. These tests should be performed at the water well or treatment plant source, fire hydrants (before and after flushing), residential water spigots and taps (inside and out), low flow areas, high consumption industrial accounts, schools, hospitals, hot and cold, new and old services alike. The more information available from the beginning allows less room for error down the road.

In order to verify dosage feed rate at the well head or treatment plant, the poundage or gallons of actual solution injected at the source can be compared to the parts per million observed at these sampling points in the system. A very stable phosphate will give consistent test readings from the source of application to the very end of the system, regardless of flow rate and temperature of sample. A decrease in phosphate content shows that the product is precipitating and reverting to the ortho state previously described. In this ortho state iron and manganese cannot be sequestered, thereby allowing discoloured water to start reoccurring in the lines. Therefore, a product with low reversion to ortho and stable properties is desired for use with high mineral content water.

This potential for reversion from complex to ortho can actually be seen by using the hot water tank comparison. The difference between the ortho going in on the cold side and the level on the hot side gives the percentage of breakdown through increased temperature. Comparing this amount reverted with the total phosphate available in the compound also shows stability to remain in the active state. Quite often they will be totally broken down before the hot water heater and will give lower readings on the hot side due to scaling out of chemical along with the hardness. Certain generic polyphosphates are known to revert several times faster than the formulated linear chain compound. In the system with low flow areas, dead-end lines, process water use, and in domestic hot water tanks, this break-down doesn't allow for complete relief of the problem. Therefore, testing phosphate reversion with a simple field test kit can give valuable information to the utility when comparing products. A material with low stability is not very cost effective. Consistent field test readings of phosphate and iron show stability.

Once the objective to clear up red water or reduce corrosion or clean-up tuberculation has been defined, it can be very easy to form trends and project the success rate through "common sense use" of test data. Anyone who has programmed or even used a computer can relate to the statement "garbage in - garbage out". A potable water system is much like a computer. The hardware can be considered as the mechanical equipment - the well pumps, treatment plant, filters, valves, water mains, service lines, etc. The software would be the chemical treatment, such as lime, alum, polymer, chlorine, fluoride, or phosphate. The relationship or interface between these two mechanisms is very critical and quite often the key to success or failure. The value of one can only be determined in combination with the other. Therefore, I want to stress the significance of this example especially for our discussion about phosphate treatment.

The phosphate program is only as good as your means of evaluation, whether it simply be customer complaint log sheets, good and rapid clean-up of hydrant flushes, or thorough laboratory studies for water flow C-factors and corrosion rates. Be it kept simple or made complex, we will all eventually hear about the success rate from the customer.

Phosphate treatment programs are subjective. Unless you have been involved with the original stages of passivation through clean-up and maintenance, it is difficult to describe the satisfaction received when "dirty water" problems have been minimized or eliminated after years of increasing customer dissatisfaction. Phosphate programs are not like lime softening, or chlorination, or fluoridation where the process either works or it doesn't.

The phosphate treatment program is relative to the severity of the problem, and dependent on the effectiveness of the prescribed additive.

Today, through the vast amount of background in field studies available for comparison, it is possible to expect absolute results using linear chain polymerized phosphates where other phosphates have fallen short in the past. There is no need to rely only on partial success. As a challenge, let some of the previously described ideas and procedures assist you in obtaining the optimum effectiveness of scale and corrosion inhibition from use of the linear chain phosphate in a complete water treatment program.

ACTIVATED SILICA TRIAL AT CITY OF EDMONTON ROSSDALE WATER TREATMENT PLANTS

Andy Maguire
Water Treatment Plant Operator
Rossdale Water Treatment Plant, Edmonton

The subject of the presentation I am giving today is on the trial use of activated silica and sodium aluminate which is commonly referred to by its brand name of Han-floc 45, at the City of Edmonton, Rossdale Water Treatment Plants.

The North Saskatchewan River is the source of raw water to our plants. Treatment of this supply can be, at times, quite challenging. Some of the plants in our province have quite a stable source of raw water, being relatively consistent in turbidity, color, hardness, etc. Unfortunately, this is not the case in the North Saskatchewan River. The turbidity can increase and decrease dramatically within a very short period of time. It is not uncommon during the spring and summer months for the turbidity to vary by 10 to 30 NTU within a couple of days, to upwards of 175 to 250 NTU within a week's period. There are exceptional circumstances when the turbidity has increased in excess of 400 NTU during spring run off.

Another trait of the North Saskatchewan River is during fall and winter months when the turbidity is usually relatively stable between 2 to 5 NTU, we can experience raw colour fluctuations. This can be quite a problem to treat, considering the usual method of colour removal is performed by the addition of alum. High colour requires pH suppression which is done at Rossdale by the addition of alum. The excess alum coagulates then flocculates but the floc particles do not readily settle due to lower turbidity and cold water viscosity. This in itself causes a number of other process problems. The need for an additional process was established in part by the previously mentioned attributes of the North Saskatchewan River.

In 1986, an in depth study was done on the "Critical Assessment of Drinking Water in Edmonton" by Dr. Steve Hrudey and Associates, outlining the quality of raw water supply, quality of monitoring, treatment practices, treated quality, options for improvements and associated cost. Numerous recommendations were made from this report. One of which is "optimize the existing process with the aim of achieving a finished water turbidity goal of 0.10 NTU". I am glad to report our City Council has approved a budget for 1987 to start much of the upgrading recommended in this report which will enable Rossdale WTP to achieve an even higher quality of potable water. Due to the positive outcome of our trial use of activated silica, an increased budget to absorb some of the costs and a true concern for the improvement of treated water quality, we have decided to pursue further trials with the use of activated silica treatment at Rossdale and E. L. Smith water treatment plants.

For those of you who are not familiar with activated silica or sodium aluminate the following is a breakdown of the chemicals, advantages and disadvantages, and improvements which can be seen in the treatment process.

Sodium Silicate: It was discovered in 1937 that the addition of a partially neutralized sodium silicate solution had a clearly visible effect on coagulation with the use of alum. It is also commonly referred to as a coagulant aide. Activated silica, when used with alum, motivates flocculation by hastening the floc formation and increasing its size, density, cohesion, and strength. The floc enmeshes suspended matter and settles rapidly therefore causing an increased removal of suspended material producing a clearer water to treat. The large, tough, rapid settling floc formed by the introduction of activated silica results in a greater reduction of turbidity. These characteristics are important particularly in cold water which is more vicious and has a longer chemical reaction time.

There does not seem to be any fixed ratio between activated silica and alum dosages, but it is frequent practice to:

1. add alum before activated silica, and
2. silica production of 7 to 11 percent of alum dose with optimum dosage of activated silica at 1.0 to 1.5 mg/L.

Sodium silicate by itself is not thought of as a flocculent aide but becomes so when a part of the alkalinity is nullified by an acid when it is then considered to be activated. Sodium silicate reacts with different activating agents to form a negatively charged colloidal particle. Sodium aluminate, sodium bicarbonate, sulphuric acid, alum, ammonium sulphate, and chlorine are the most common activating agents.

A couple of reasons were established for the use of sodium aluminate at Rossdale. One being the alumina content in sodium aluminate could be, and was, used as an alum supplement. Secondly, at the time of consideration for an activating agent, technical and practical information was quite readily available on sodium silicate applications.

The innate silicate content of raw water has no relevance on the use of activated silica, even if it is high. Natural silica in water is in a structure that does not benefit coagulation. Actually, the use of activated silica in the treatment of raw water generally reduces the silica content of the finished water due to more complete coagulation obtained.

Sodium aluminate, registered brand name Han-floc 45, is an economical source of high purity and greatly reactive anionic alumina which can be precipitated fully. When used with cationic alum as a partial substitute or as a supplementary source of alumina, it is instrumental in the more thorough precipitation of alumina in addition to supplementing a reduction of soluble sulphate ions.

Sodium aluminate contains virtually three times more alumina than alum besides releasing some alkalinity.

Coagulation is the term for the technique used in treating water with certain chemicals for the accumulation of colloidal and finely divided suspended matter or non-settleable particles, into larger, heavier aggregate which is easily extracted. This suspended matter is normally found to have an anionic charge. Coagulation depends on the addition of highly charged positive ions. Optimum coagulation hastens a better removal of algae, bacteria and virus, and non-uniform organic substances. Some of the needs for coagulant aides are small slow settling flocs, low water temperature which increases waters viscosity, carry over of a coagulant chemical, poor low water temperature floc formation, and fragile flocs.

Flocculation is the moderate stimulation of chemically treated water. This process influences the clashing of small floc particles causing them to adhere to one another and develop into larger more settleable masses.

Some of the affirmed advantages and disadvantages found in using activated silica are as follows:

Advantages	- increased floc size
	- lower cost over primary coagulants due to lower dosage with higher activity
	- high chemical stability
	- effective low temperature performance
Disadvantages	- precise process control necessary
	- incorrect dosages could be detrimental to plant process
	- higher maintenance of system necessary

System Design: The task of designing the pumping, mixing, and injection system was basically quite simple. The system was designed to deliver sodium silicate and sodium aluminate solutions from exterior chemical trailers through independent metering pumps. From there, the mixed solution was gravity fed to a holding tank where it was diluted with water. The diluted solution was then pumped into the raw water piping system.

A few concerns had to be addressed in the system design. Some of these were found after the system was installed and functional necessitating modifications.

1. A backup pump from the chemical storage to the reaction chamber.
2. A backup pump from the holding tank to the raw water injection point.
3. Due to the fact that the dilution water emerges from a potable service water line or that it has a direct connection to a potable water supply outlet, a backflow prevention device must be installed.

4. An adequate total system flushline is necessary.
5. The holding tank should have a level controller and overflow drain line from the dilution water.
6. A mechanical device ought to be installed in the mixing tank to maintain uniformity of chemical mixing.
7. Line pigging facilities.
8. Due to the nature of sodium silicate solution it starts to freeze at relatively low temperatures. The trial basis was held during summer and early fall therefore external chemical storage was not a substantial difficulty. If the system was to be in operation on an annual basis, a method of temperature control would have to be contemplated.

Observations

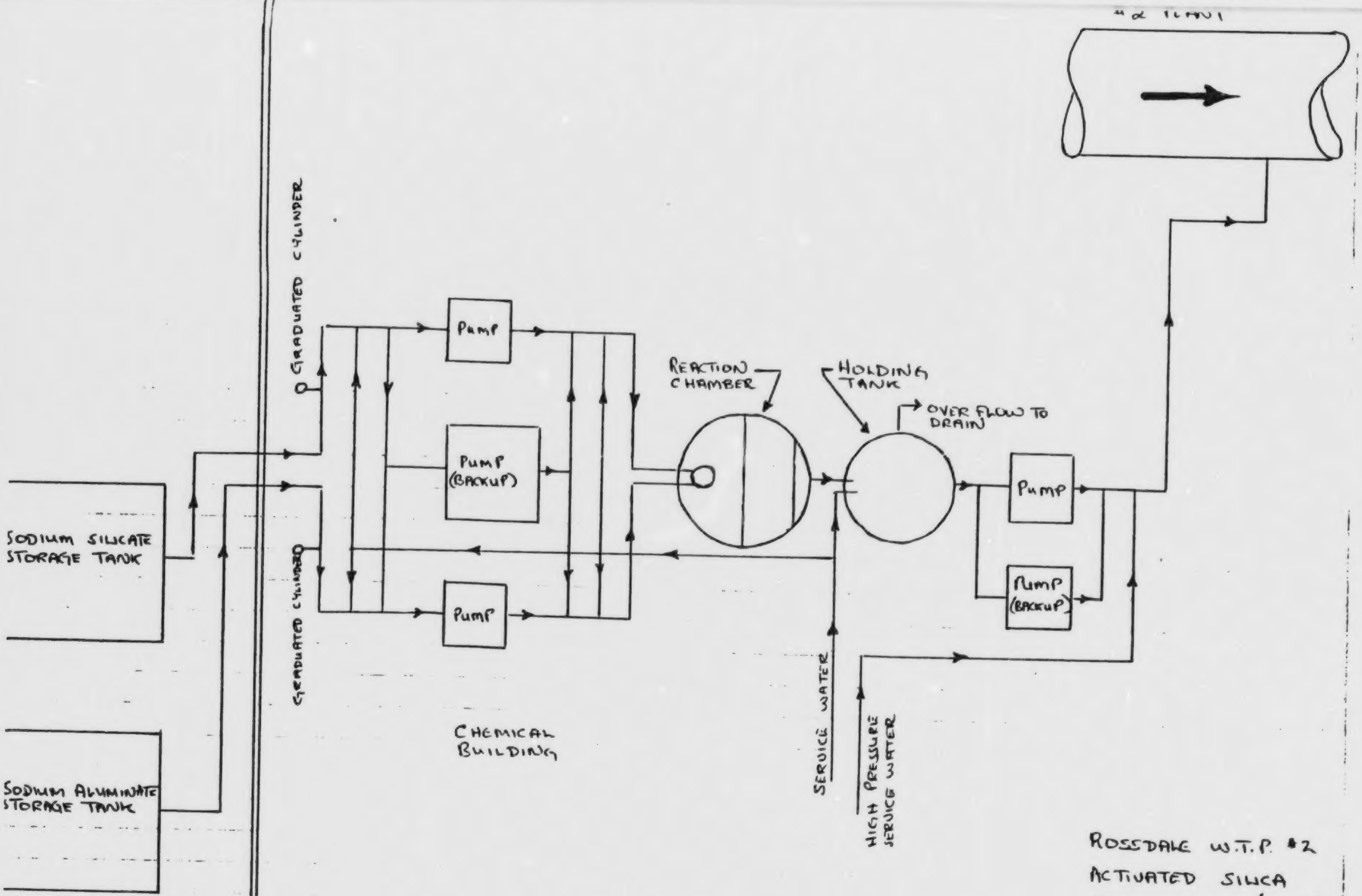
Clearly, the most significant observations from this trial was the exceptional reduction of turbidity in the alum coagulation stage of treatment and the reduction of liquid alum chemical used. Also noted was a reduction in filter loading therefore reducing the amount of filter backwashing. The turbidity was reduced by approximately 47 percent overall in the coagulation stage with an average monthly flow of about 26 percent more through the trial production plant with an overlap reduction of approximately 4 percent of liquid alum chemical used.

During spring runoff conditions in the latter portion of May and the first week of June causing turbidities of the raw water to increase up to 275 NTU and raw colour up to 40 TCU, plus a flood of the North Saskatchewan River during the last two weeks of July again causing a rise in raw water turbidity of approximately 330 NTU and raw colour of 105 TCU, the plant's chemical consumption increased immensely. The estimated cost of alum coagulation without the silica treatment during this trial basis was approximately $7.15/mL produced and with the silica treatment it was $7.94.mL produced. The total cost per mL of water produced would have been less expensive if a few conditions could have been alleviated. For example, due to the operational controls of the new chemical feed system, some judgement decisions on feed rates could have been more precise and probably lower if personnel were more familiar with the equipment. Secondly, some system problems were experienced which is common on a practical test of new systems. During our runoff period in June the silica system was shut down due to improper gel formation on system start-up. In the time of the last week of July a chemical feed line from the sodium silicate chemical tanker to the metering pump ruptured causing the complete system to gel and plug. Also, some line scaling and plugging was experienced in the system during the latter portion of August at which time the system was taken out of service for inspection and line replacement. During these times when the trial system was not working the alum feed rates in the coagulation stage where the trial was taking place had to be increased up to 51 mg/L to compensate for the loss of silica and aluminate. These were the majority of problems experienced during the trial run and some justifications for the factors causing an increase in the cost per mL produced.

Future Systems: At present Rossdale is again in the design process of a new silicate-aluminate system. It is intended to be operated prior to the lime softening stage. Due to the significant reduction and relative ineffectiveness on pH values, sodium silicate combined with sodium aluminate are said to be effective in removing both carbonate and non-carbonate hardness from treated water without the use of caustic soda or soda ash. Also, improved coagulation in the sedimentation basin due to the production of aluminium hydroxide can be noted. Finally, by the use of sodium aluminate as a method for removal of magnesium hardness rather than excess lime, we feel that the new process system can be both quality control efficient and cost effective.

This in effect completes my presentation. Rossdale operations feels the trial was very successful not withstanding certain minor irregularities with the experimental process. We are also anticipating the future process. As stated at the beginning of this presentation, if anyone wishes further indepth information or a copy of this presentation, please feel free to contact me at any time.

I would personally like to thank Mr. Patrick McManus from Canada Colours and Chemicals Limited in Edmonton and Mr. Tom Prediger from Hydro Tech in Vancouver, B. C. for their seemingly endless amount of information and support during the preparation of this presentation .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OVER FLOW TO DRAIN
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HIGH PRESSURE SERVICE WATER
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ROSSDALE W.T.P. #2
ACTIVATED SILICA
FEED SYSTEM (TRIAL)
- SCHEMATIC PLAN -
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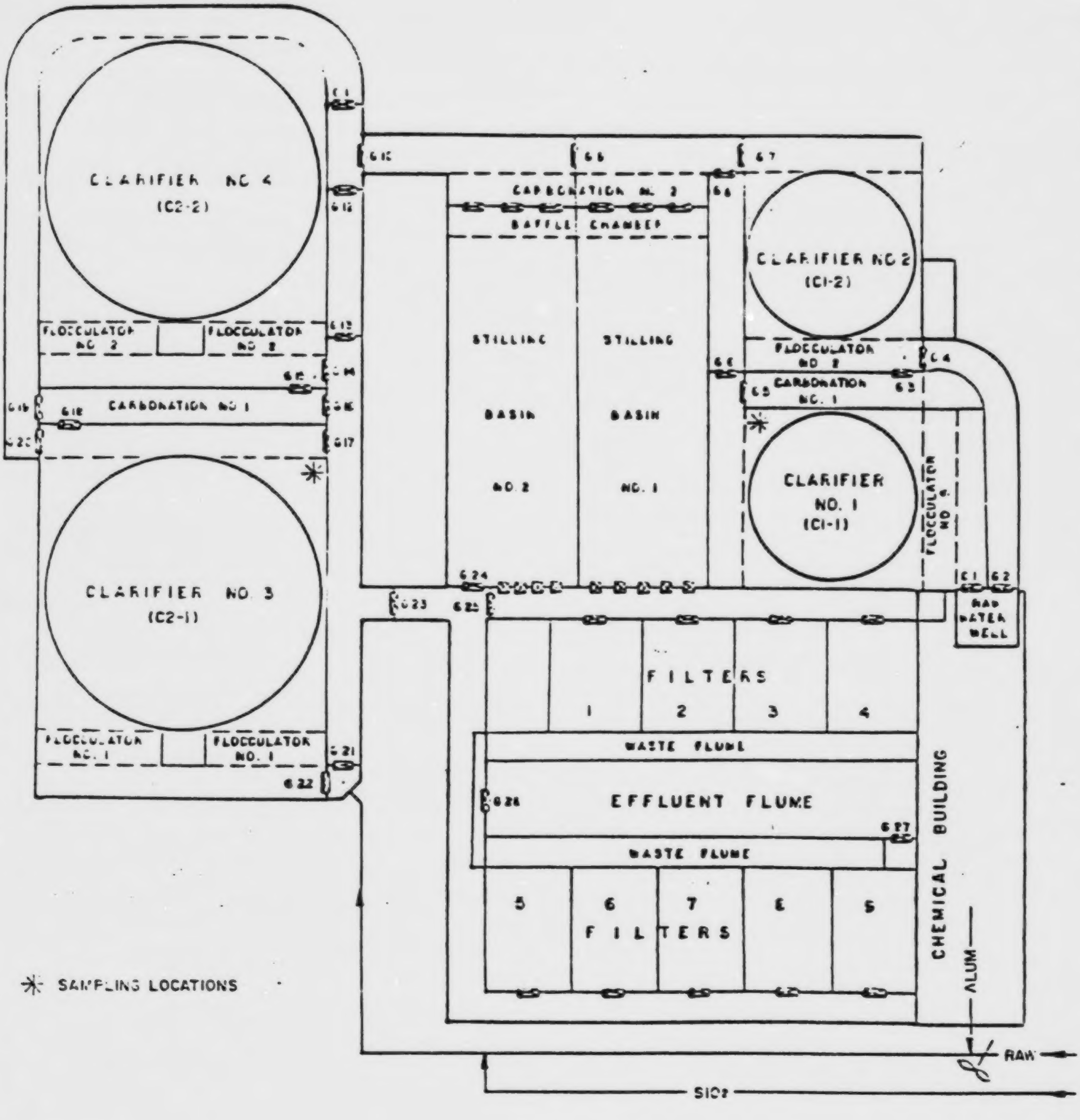
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FLOCCULATOR NO. 1
CARBONATION NO. 2
BAFFLE CHAMBER
STILLING BASIN NO. 2
STILLING BASIN NO. 1
CLARIFIER NO 2
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G 22
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FILTERS
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WASTE FLUME
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FILTERS
CHEMICAL BUILDING
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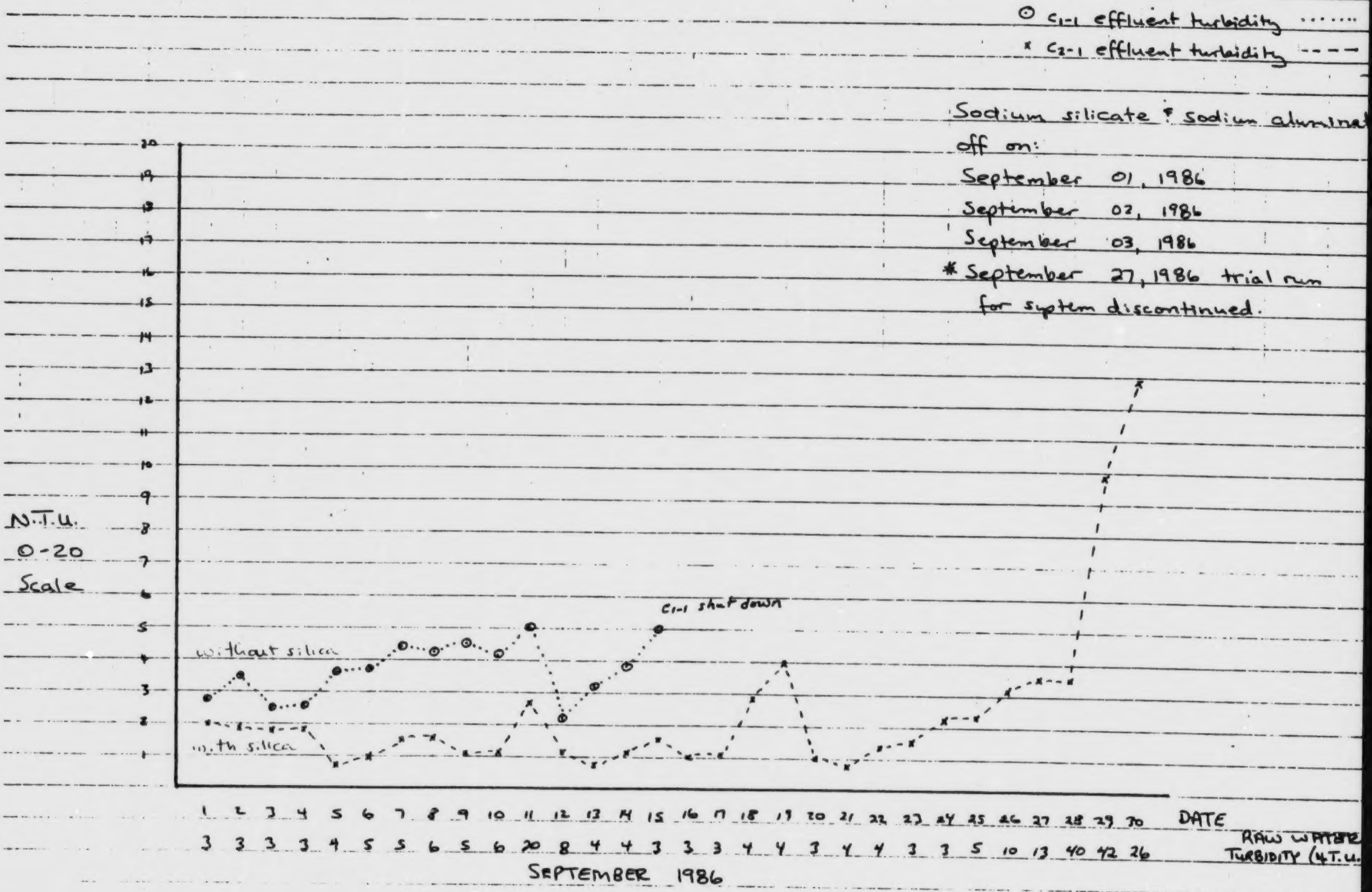
SAMPLING LOCATIONS

ACTIVATED SILICA TRIAL AT ROSSDALE W.T.P. No. 2

Scale : N.T.S.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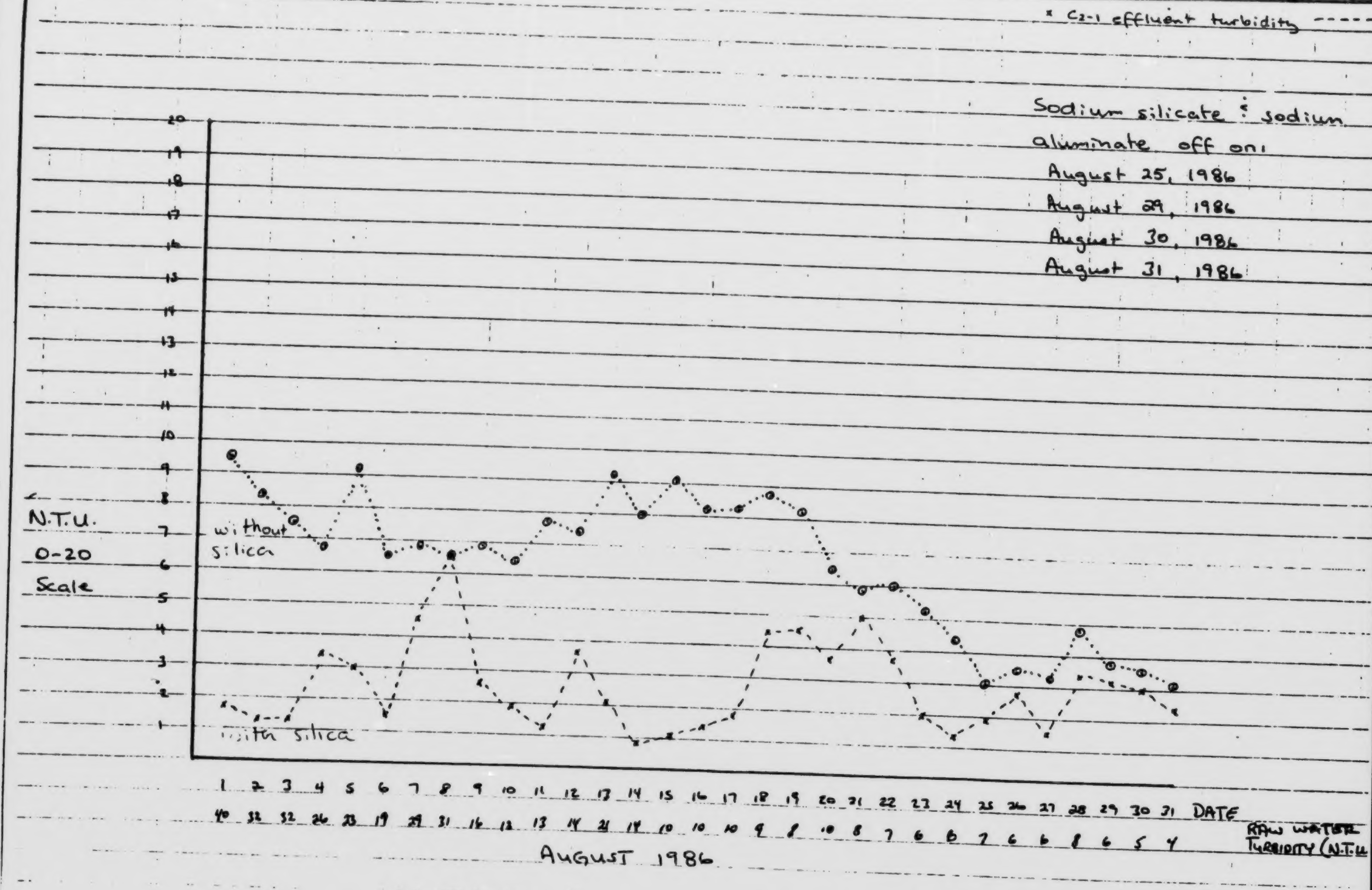
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AUGUST 1986

HISTORY OF METERING AND METER READING

Gavin Morcon, Product Manager
Neptune Meters, Toronto

The purpose of this seminar is to illustrate and explain the changes in water meters and reading systems that the industry has seen over the last 60 to 70 years. We, at Neptune, regularly find a great deal of resistance from municipal utility operators towards any product changes that we make. Typically this resistance comes about because of the solid performance of the now obsolete product, and because of the lack of understanding as to why the product changes have been made.

Style 2

To begin with, Neptune introduced the Style 2 water meter to the Canadian market in 1919. This meter had a positive displacement measuring chamber in its bottom section that drove a register in the top section by means of a mechanical shaft that turned through a stuffing box. The stuffing box used a leather washer to prevent water leakage in the measuring chamber section of the meter from bypassing the shaft. To prevent the leakage that would occur over time, the stuffing box had to be constantly tightened, thereby destroying the washer so that it needed to be replaced, and gradually reducing the ability of the mechanical drive to turn, so water registration was lost.

The Style 2 incorporated a nutating disk measuring chamber as have all generations of small Neptune water meters. The nutating disk measuring chamber used a wobble plate located in the measuring chamber and is forced to nutate as water passes through the measuring chamber. The design has a very small wear area resulting in a quiet and long lasting meter. The nutating disk allows small particles to pass through the measuring chamber without being trapped. Also, with the nutating disk, the centre of effort remains constant resulting in a quiet meter.

The Style 2 has been a very successful product with many of this type of meter still reliably in service.

Trident Seal

To solve the stuffing box difficulties, Neptune introduced the Trident Seal meter in 1963. The Seal used a magnetically driven register to eliminate the requirement of a stuffing box. As a result, the measuring chamber and the register were now separate components, leading the way for register interchangeability in the future.

The Trident Seal was also a significantly downsized meter. The smaller measuring chamber improved the low flow accuracy because of the increased number of nutations required to measure each unit of water. This is very important because a domestic water meter operates at very low flows for approximately 90 percent of the time and any improvements in low flow accuracy results in increased revenue capture for the municipality.

The smaller meter also resulted in improved material usage and less production machining requirements making for a less costly product. These cost savings are passed on to municipal customers in the form of lower prices.

Trident T8

To continue with the design philosophy of offering superior products at lower prices, Neptune introduced the T8 in 1972. This meter was downsized considerably over the previous Trident Seal and still smaller measuring chamber resulted in another improvement in the low flow accuracy thereby increasing the possible revenue capture of the utility. The optimized size and weight resulted in another significant improvement in material and production costs to be transferred to the customer in the form of lower relative prices.

This was the first meter to make an extensive use of synthetic polymers for measuring chamber components and register gears and parts. Improvements in injection moulding techniques and plastics machining made this an obvious progression for producing long lasting and low cost water meters.

Trident T10

To take the overall objective of offering a low cost product with improved customer benefits even further, Neptune introduced the T10 in 1981. This is the first meter to be completely designed by computer using a CAD package.

The measuring chamber has been further downsized for the T8 so that it is now at the minimum size allowed under AWWA specifications. This has resulted in an accuracy of +/- 1-1/2% at 1/4 GPM.

The smaller meter body improves material usage and reduces production machining resulting in a lower cost product. The meter body spuds have had a change in shape from being straight on the T8, to being triangular on the T10. Triangular spuds are stronger than straight ones, especially in installations where the piping is misaligned because the stress loads are now more evenly distributed over the whole meter body. The triangular spuds also allow for improved water flow throughout the meter resulting in a lower head loss.

The T10 meter has a redesigned register that incorporates a small red low flow indicator on the register facing. The low flow indicator is directly driven by the nutating disk and will register extremely low flows such as faucet or toilet leaks. This gives the municipality the opportunity for improved customer service where a customer is complaining of an inordinately high water bill as the low flow indicator will give a quick check for leaks in the system to justify the high water bill.

We recommend that a municipality regularly test a sample of the small meters in their system to check meter accuracy. A great deal of attention should be paid to the accuracy of the meter at low flows as this is where the meter normally operates for the majority of the time. If the meter is at all inaccurate at low flows it will not take long to pay back a new meter and the old one should be replaced.

To summarize the design changes in the small domestic water meters, there has been a constant downsizing of the meters to improve meter accuracy, improve material use and ease of manufacture. There has also been an increase in the use of lower cost materials such as plastics. This has left us with a meter that is available at a lower relative price and has greater customer benefits such as improved revenue capture, lower maintenance costs, and improved customer service possibilities. The large meters have undergone a very similar transition to that of the small meters, beginning with the Crest meter.

Trident Crest

The Trident Crest meter was introduced to the Canadian market in 1919. The meter incorporated an AWWA Class I turbine with a vertical orientation. The turbine meters are inferential meters in that they infer a water volume based on the velocity of the water passing through them.

The single register was driven mechanically by means of a shaft that passed through a stuffing box.

This meter was very successful with many of them still reliably in service. The Crest meter is still made in 2 inch and 3 inch sizes for specific industrial applications but it is very expensive.

Trident Turbine

In 1978, Neptune introduced the Trident Turbine meter incorporating an AWWA Class II turbine element with a horizontal orientation. This measuring element is also inferential. It incorporates state-of-the-art materials such as synthetic polymers, tungsten carbide and graphite bearings. The result is a measuring element that has almost the same specific gravity as water to reduce torque and have great accuracy over a very wide range of flows. This meter is significantly more accurate at low flows than the Crest meter.

Similar to the progression in the domestic meters, the new Turbine is tremendously downsized making it lighter and easier to work with. Material usage and machining requirements are significantly improved resulting in a lower cost, lower price product.

The register on the Turbine meter is magnetically coupled to eliminate stuffing box problems and allow for register interchangeability.

The Turbine incorporates the Unitized Measuring Element principle allowing the measuring part of the meter to be completely removed while leaving the meter body in line. This provides for much easier servicing as a temporary UME can be easily installed allowing for the continued use of the line and water consumption registration. The UME is much more easily repaired when removed from the meter body in this fashion.

The UME also has a calibration vane that will provide easy calibration of the turbine element of +/- 5%.

STRAINERS

All Turbine and Compound meters should be installed with a strainer in front of them. The strainer protects the fragile turbine elements from being damaged by debris in the water system. The strainer also acts to improve the flow profile of water entering the meter thereby making the turbine elements more accurate.

Old Style Compound

The Old Style Compound meter was introduced by Neptune to the Canadian market in 1919. The Compound meter has three basic components - and AWWA Class I turbine to handle large flow rates, a small nutating disk measuring element to handle low flows, and a gravity valve to divide the water flow between the two elements.

The Compound meter has two registers, one for each measuring element, that are both mechanically driven through stuffing boxes. The total registration for the meter is obtained by adding together the totals of both registers. By having separate registers for the high flow and low flow elements, it is much easier to diagnose where problems with the meter are and fewer parts are required to make the meter work.

Water, during low flows, enters the turbine side of the meter, bypasses the turbine element because the valve is closed and enters the nutating disk chamber to be measured, and then exits the meter. As the flow rate increased, the differential pressure across the valve becomes greater, thereby forcing it to open. As the valve opens, increased flows are allowed through the turbine element for high flow rate registration. The crossover rate of the valve is quite wide, and it is in this flow range that the meter loses a significant amount of its accuracy.

Trident Tru/Flo Compound

To address the weaknesses of the Old Style Compound meter, Neptune introduced the Tru/Flo Compound. This used the same three basic components as the previous generation, but now each component has been dramatically improved.

The AWWA Class I Turbine element has been replaced with the AWWA Class II Turbine element, the same as that used in the new Turbine meter.

The older nutating disk has been replaced with the measuring chamber from either a T8 or T10 meter thus giving the improved low flow accuracy of the smaller measuring chamber.

The crossover valve has been completely redesigned so that now it is spring loaded instead of gravity loaded. The new valve has a much narrower crossover range to reduce the loss of accuracy during these flow rates. The valve is also shaped such that, during the crossover range, the flow reaching the turbine element is conducive to improved accuracy thereby increasing the meter accuracy during the crossover period. The 4" and the 6" compound meters actually use a small spring loaded valve within a large valve to further improve the accuracy of the larger meters during crossover.

Even during very high flows, there is some water allowed through the nutating disk to prevent sediment build up.

The registers are now magnetically coupled to allow interchangeability and eliminate stuffing box problems. The total meter registration is still obtained by adding together the registration of both registers. Dual registers still allow for ease of troubleshooting and require fewer moving parts.

The Tru/Flo Compound meter used the UME measuring principle the same as the Turbine meter. The turbine section of the UME also incorporates a calibration vane for calibration of the turbine element +/- 5%.

The much smaller and lighter Tru/Flo Compound is easier to handle and has improved material usage and reduced machining requirements for significantly cheaper production costs.

The same kind of dramatic improvements in the Turbine and Compound meters have been made in the fire service meters.

Protectus I

Protectus I is a very large meter (the 6" weighs 1200 pounds) introduced to the Canadian market by Neptune in 1919 to be used for fire service applications. Protectus I is a proportioning meter in that it only measures a portion or roughly 30% of the water passing through the meter.

Protectus II

Protectus II was introduced in 1980 to make use of modern metering methods for fire service applications. Protectus II is an integrated meter made up of four main components. A large basket type strainer is used to prevent debris from entering the meter and blocking the water path. An AWWA Class II Turbine meter is used to measure water during high flow periods such as during a fire fighting period. The Turbine meter is identical to the current Turbine, except that the meter body has been reinforced to improve pressure handling capabilities. A small T10 bypass meter is used to register water during low flow periods where authorized water usage from the fire service line is permitted. A detector check valve is used to divide the water flow between the two measuring elements depending on the differential pressure across the valve. All components meet or exceed UL and FM requirements for insurance and liability purposes.

The complete meter is an integration of the components resulting in a product that is very accurate over a very wide flow range. The Protectus II is easily serviced in that individual components can be removed and the Turbine meter incorporates the UME principle. The bypass T10 meter has a low flow indicator for detection of leaks in the water system. The complete unit is less expensive to manufacture than Protectus I resulting in a lower priced product.

Protectus III

Protectus III is being introduced to the Canadian market this month. This meter uses very similar components to those of Protectus II but now the body components are more integrated to produce a meter with a shorter laying length. The body components have changed from cast iron to prefabricated steel for a significant weight reduction.

All large meters should be tested every 12 to 18 months. The large meters will generate a large percentage of the revenue in any water distribution system so extra attention should be paid to their accuracy. It takes very little time to pay back a new meter if the existing meter is only 3% to 4% inaccurate.

The same degree of improvements that have been made in the measuring elements - the positive displacement, turbine and compound meters, have also been made to the registers.

Standard Registers

In the past, all of our meters used a standard reading register that was either mechanically or magnetically driven. This is a very reliable product with many of this register type still in service.

In order to take a reading, the meter reader has to gain physical access to the meter. This has become an increasing problem over the years with more and more dual income households making it more difficult to be able to read the meter. There has also been a municipal customer service concern due to the increasing resistance to allowing a stranger into customer homes.

Remote Registers

To solve the problems associated with having to gain access to the meter to take a reading, meter manufacturers introduced remote metering products in the mid-1960's. The meter register is constructed with a small electromagnetic pulse that drive an external odometer affixed to the wall of the building.

The main problem with pulse generating remote systems is reading integrity. In any system using this register, we consistently see a significant number of meters where the internal odometer is reading different than the external odometer reading. These problems can be attributed to the failure of the pulse generator to generate a pulse, or by the failure of the receiving unit to turn the external odometer correctly as a result of receiving a pulse.

Another contributor to the reading integrity problem is the external odometer is affected by weather and by such things as children kicking a ball against the wall where the remote unit is located.

Every RM meter should be tested every 12 months to compare the external odometer reading. This will help reduce customer service problems caused by inaccurate bills due to this reading integrity problem.

Electronic Registers

With a view to leading the way to more sophisticated reading systems, Neptune introduced the electronic ARB register in 1965. The ARB I was a transistorized register that was attached to an external receptacle by way of a 14-wire cable. Many municipalities experimented with the register but found it very difficult to work with because of the cumbersome 14-wire cable.

Neptune continued to develop and improve electronic registers because of the long term benefits that they provide the municipality. The callback problems of the standard register are eliminated because the remote receptacle means that the meter reader does not have to gain physical access to the meter to take a reading. The reading integrity problems of the pulse generation system are eliminated because the reading equipment electronically interrogates the register wheelbank position. The register works similar to a car's distributor, but only in reverse. Now the odometer wheel, or "distributor cap" turns and the circuit board, or "rotor" remains in a fixed position. The reading equipment provides power to a completed electrical circuit, its path depending on the odometer position. Because we are taking a reading of the actual odometer position, reading integrity problems are eliminated.

The ARB meter has improved tamper resistance. If the wire to the receptacle is disconnected and then re-connected, there is no loss of external reading accuracy because the reading is being made of the register odometer that has still been turning. If this were to occur on a pulse generator system, pulses would have been lost and the external odometer would have become inaccurate.

The recent generations of the ARB register incorporate standard 3-wire telephone wire which is much easier to work with than the 14-wire cable. Furthermore, the transistors have been replaced by silicon chip. This chip converts the information about the wheelbank position to a digital signal. Because we now have a digital signal at the register, we can employ several types of sophisticated electronic reading equipment.

Electronic Gun

Historically meter readers have carried a pencil and route-book to do readings on Standard and pulse generator remote meters. With the electronic registers, the meter readers now have to carry a small electronic reading gun to perform a reading. The gun provides the electrical power to the register to activate the silicon chip. The chip then provides the reading information to the gun where it is displayed on a small LCD screen on the side of the gun. This reading is then recorded in a route-book by the meter reader.

Electronic Route-Book

The next generation of electronic reading equipment that we have available is the hand-held PBM computer. This computer serves as an electronic route-book to store readings and guide the meter reader through the route.

The PBM is a small portable computer with a 256K bubble memory. The unit will operate form $^-30$°C to $^+70$°C and will operate in rain or snow storms. The unit can be used to automatically read electronic registers by means of a gun attachment, or it can be used as a manual entry device for standard or RM water meters, and gas and electric meters. When reading the electronic ARB meter with the PBM with the gun, a complete electronic circuit is formed between the computer and the meter odometer. This maximizes reading integrity and minimizes data transportation errors. Data transposition errors are further reduced because the information is electronically moved from the PBM hand-held computer to the billing mainframe computer eliminating keypunch mistakes.

Automatic Meter Reading

While the PBM data capture device represents a significant advance in meter reading technology, the ultimate is automatic meter reading where the meter is read automatically by a central computer using telephone lines to transfer data.

The basic component of this system is the electronic register because it provided a digital signal source. The ARB meter is connected to a black box in the customer's home which, in turn, is connected to the telephone line.

The mainframe computer, located at the municipality's office, can call up the meter by using the telephone test trunk equipment to obtain a reading. When this process is completed, an electronic circuit will have been formed between the municipal computer and the odometer wheelbank of the meter for maximum ease and integrity of reading.

Because the CMR system employs the test trunk equipment, there is absolutely no interruption of the customer's regular telephone service. The system does not ring the phone in the customer's home and can sense when the phone is being used so as not to interrupt a phone call.

The CMR system is technically feasible for water, gas and electric meters. It is some years away from being economical for a smaller utility, though.

Summary

In summary, both meters and meter reading equipment have undergone tremendous changes over the last 60 to 70 years. The industry has constantly introduced new technologies to offer products that provide better value to the municipal customer.

Reading systems are being constantly improved to provide more reading efficiency and minimize the chances of errors. Furthermore, the new products dramatically improve the customer service opportunities for the municipality.

CHEMICAL FEED TROUBLESHOOTING

J. B. Hambley, P.Eng.
President
Anthratech Western Ltd.
Calgary

The importance in a water treatment plant of good reliable chemical feed equipment is obvious. Faulty equipment results in overfeed and underfeed of chemicals, line plugging, high maintenance, poor plant performance and endless frustrations for the operator. We have all seen the end results of poor chemical feed equipment: equipment that bears little resemblance to the original, Moyno pumps in pieces, Silo sides battered in, lines plugged up, PVC lines knocking apart, etc.

Very seldom are chemical feed problems the fault of the operator. The basic problem lies often both in the original design (not suitable for the purpose or something has been overlooked) and with the equipment supplier who has supplied equipment that is not suitable for the purpose in some way. Anyone can make a mistake, but we seem to have been making the same mistakes for too long. We will zero in on the common root causes of problems, and some of these are not at all obvious. Hopefully, this paper will get you thinking about some of your own problems from a bit of a different slant.

The group of chemicals that are the most troublesome are those we refer to as reactive chemicals:

Lime - $Ca(OH)_2$
Soda Ash - Na_2CO_3
Caustic Soda - NaOH
Calcium Hypochlorite - Ca(OCl)Cl
Sodium Hypochlorite - NaClO
Sodium Aluminate - $Na_2Al_2O_4$

All chemicals are, of course, reactive but these chemicals above are particularly troublesome because when you add water to make up a solution, or in the case of lime - a slurry, will react with the dilution water hardness or alkalinity of both to form scale in the chemical pump and in the feed lines.

If you feed an "unstable" solution of these chemicals, that is, one in which the reactions between the chemical and the hardness and alkalinity in the dilution water have not been completed, then you have big trouble.

There are a number of volumetric feeders on the market, including these descriptive types: undercut gate, screw conveyor, roll feeder, revolving plate, apron or belt feeder, plunger feeder, reciprocating plate feeder, vibratory feeder, flight conveyor, oscillating hopper, and star feeder.

The oscillating hopper, revolving plate, star feeder, belt feeder, and helix feeder are the most common types used in water treatment plants.

We also see a number of different types of gravimetric feeders used in the industry, where accuracy of feed rate control is required. All of these chemical feeders, both the gravimetric and volumetric are normally arranged to feed in proportion to a flow. None of these feeders are without their troubles, some more than others, and we do not intend to discuss this here.

The main problem starts when the chemical is discharged from the feeder into the dissolver tank. The dissolver tank is usually equipped with a float controlled make-up water inlet, an agitator, and designed to provide three to five minutes retention time, not enough time to complete the reactions.

Let us discuss feeding lime at some length. Feeding lime has an additional complication, it is poorly soluble and it is fed as a slurry. We can learn a lot by looking at feeding lime that will apply to other reactive chemicals.

Hydrated lime slurry is quite easy to keep in suspension. It is made up as a five to ten percent slurry and about four feet per second lime velocity is plenty to keep the slurry from settling out. What happens though is that slurry settling is blamed for line pugging and pump plugging when that is not the problem at all. If the chemical reactions between the calcium hydroxide and the hardness and alkalinity and sometimes sulphates of the dilution water do not have sufficient time to complete before feeding, if you have neglected this aspect in a design, you will have more troubles than you can believe possible.

When reactive scaling occurs, people generally do the wrong things to correct them, thinking that the problem is one of slurry settling. For example, they might add water to the pump discharge to increase velocity, they might change the line size down to increase velocity, sometimes they will change the line size up, figuring that more area will give longer times between plugging. Sometimes people will put in routine periodic acid feed to clean the line. Repeat, if you maintain 4 fps minimum velocity in the lime slurry line there is no problem with slurry settling. Vendors of equipment often give bad information and we will quote the following from literature of a manufacturer of chemical feeds who shall remain nameless:

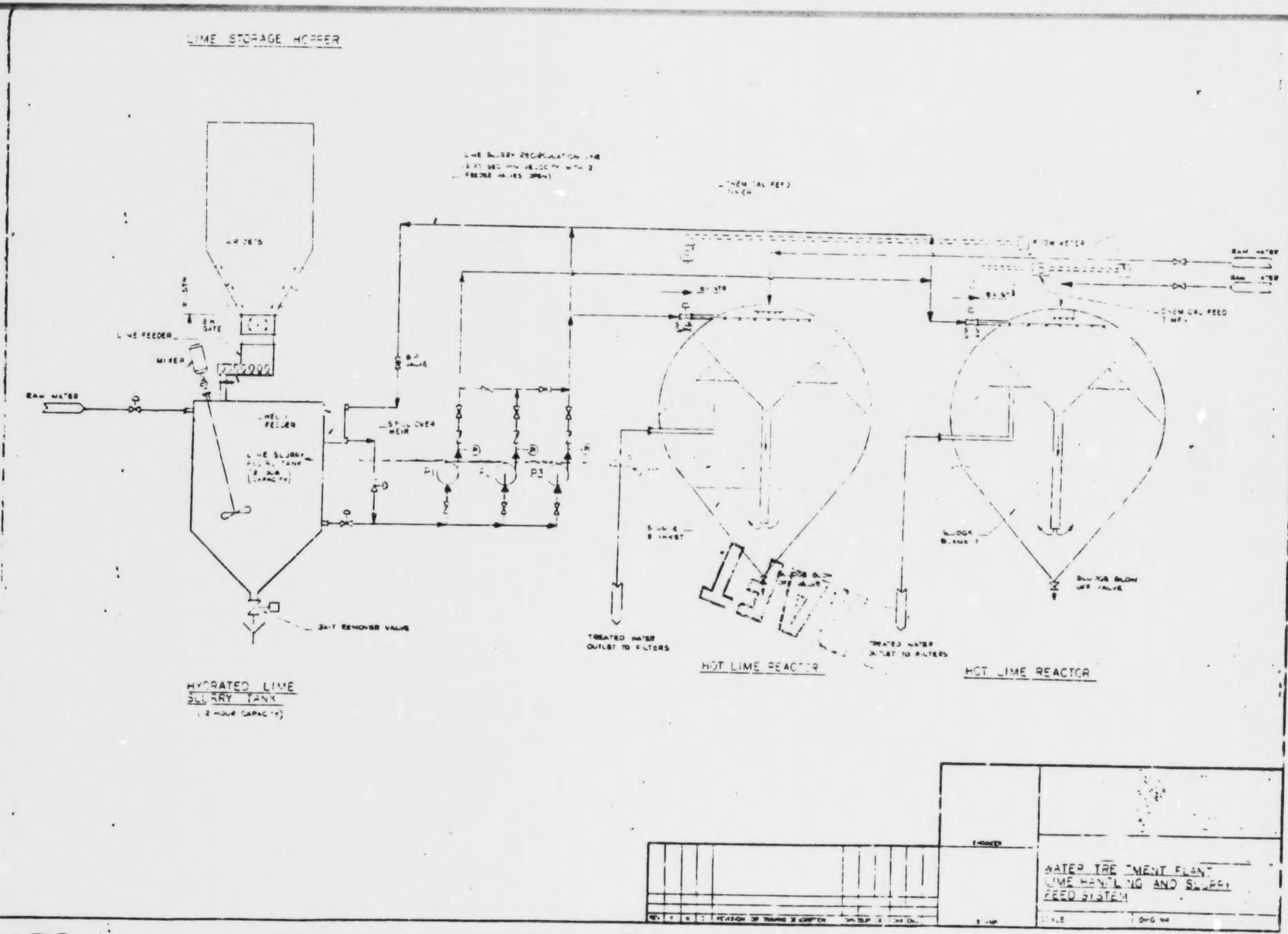
> "Dissolvers for dry hydrated lime feeders are usually designed to provide three to five minutes detention, when forming a six percent solution (0.5 lbs/U.S. gallon water) at the maximum rate of feed required. Pumping milk of lime is accomplished with open impeller centrifugal pumps. These are usually iron body and impeller, bronze trim pumps. To avoid formation of a hard scale in the pump impeller (that is, plating out) soft water should be used in the dissolver. Make-up tanks are generally used with pumps, so the pumps can operate at full capacity all the time and not draw in air. To avoid plating out, this make-up water must also be softened. In some softening plants the problem of plating out in transport pumps for lime has been solved by using return sludge in the make-up tank. The pump discharge can be throttled to reduce the amount of make-up used.

> Turbine type pumps are not satisfactory for pumping milk of lime. Eductors, also, are not satisfactory for transporting lime slurry, again due to plating out. An eductor may be used if soft water is employed to operate it. The ratio of operating water to solution pumped is about 1:1 based on the maximum capacity of the eductor. The pressure of operating water must be four times as great as the pressure against which it is pumping."

The above information is very misleading. If water is used, which has already been lime softened, plating out is certainly reduced over that from the use of raw water, but the great amount of lime present will push the softening reaction further and will cause serious plating out. If we were to go to the expense of putting in a zeolite softener to supply water for this type of system, we would be cruelly disappointed to find that although the calcium and magnesium has exchanged for sodium that the alkalinity is now sodium bicarbonate which is very reactive with lime to precipitate out calcium carbonate. The use of return lime softened sludge to the slurry make-up tank is unlikely to be very helpful. We think an eductor is not a good thing to use here, even if soft water is employed to operate it. Our conclusion is that there simply is no good way to make these types of systems operable. Basic changes are needed in the solution preparation or slurry preparation and in the control system itself.

The key thing again is to give the dilute chemical, or slurry, enough time to stabilize, that is, the reactions with the dilution water are complete before pumping into the system. With lime and cold dilution water, this requires fifteen minutes minimum. When a freshly made concentrated lime slurry is placed in an agitated storage vessel for about fifteen minutes, the precipitated salt crystals are formed and maintained in suspension. Crystallization of calcium carbonate, magnesium hydroxide, and gypsum tend to occur on existing suspended crystals, and don't plate out on anything else. This is what is meant by stabilization, due to the very cold dilution water that most of our plants have.

Figure 1 shows a highly recommended way to feed lime. The concept basically is to prepare a batch of lime slurry and give it plenty of time to become stabilized. The stabilized slurry is pumped around a loop recycle system, back into a satellite tank on the side, or sitting beside the main lime slurry batch tank. This smaller tank has a spillover weir to the main tank and thus it always holds one to two hours supply of stabilized lime. When the main tank is down to low level and another batch must be prepared, the main pump suction valve is closed and the valve from the satellite tank is opened, so the recycle pumps continue to circulate stabilized slurry from the side satellite tank which has sufficient capacity to last during the make-up period of a new stabilized batch. Dosage control is now different; the lime slurry is discharged to the point of application via a rubber pinch valve, open for varying fractions of a minute, proportional to raw water flow. (The same system would be used on small plants, where bagged lime is used.)



WATER TREATMENT PLANT
LIME HANDLING AND SLURRY
FEED SYSTEM

LIME STORAGE HOPPER
LIME SLURRY RECIRCULATION LINE
CHEMICAL FEED
LIME FEEDER
MIXER
RAW WATER
SLIDE GATE
LIME SLURRY FEED TANK
SPILL OVER WEIR
P1
P2
P3
GRIT REMOVER VALVE
HYDRATED LIME SLURRY TANK
(2 HOUR CAPACITY)
TREATED WATER OUTLET TO FILTERS
HOT LIME REACTOR
SLUDGE BLOWOFF VALVE
CHEMICAL FEED
TREATED WATER OUTLET TO FILTERS
HOT LIME REACTOR
RAW WATER
ENGINEER
SCALE
DWG NO

Another thing to watch for is the seal water supply to recirculating pumps. This would be controlled to as low a flow as possible, because the seal water will be reactive with the lime slurry.

Treat any line flush system with great care and flush only when the system is to be shut off for a while.

The calibration of the transfer auger from the lime silo will be suspect. Check the strength by weighing a litre of the slurry until you have enough lime transferred over.

Soda ash is often fed with a volumetric and gravimetric feed setup as discussed above for lime. Soda ash is reactive with water hardness particularly any permanent hardness and to a degree with the nonpermanent hardness due to caustic generated by the hydrolysis of the soda ash. Ash is very soluble, we don't need to go to a recycle loop system as discussed for lime. A satellite tank is highly recommended piped and valved into the system so that it can be filled with a stabilized solution of soda ash and then valved off. Thus, this satellite tank of stabilized solution is available for feed when a new batch is being made up in the main tank.

The same recommendations are made for caustic or for sodium aluminate, which has a highly caustic reaction. If you have to feed these diluted down then the satellite tank system, as discussed for soda ash, is recommended. Most places using caustic, use liquid caustic, and similarly liquid sodium aluminate. With the small accurate proportioning pumps available now, it may be possible to feed these chemicals neat.

Calcium hypochlorite is very reactive with dilution water due to the way it is made, which is by chlorinating lime. Therefore, calcium hypochlorite almost always has some excess lime present, which again will react with hardness of the dilution water. The satellite tank system is recommended if you are feeding calcium hypochlorite.

Sodium hypochlorite is reactive due to its caustic residue. It is made by chlorinating caustic soda. Most plants using sodium hypochlorite are small and use only a very small amount per day. It comes as a liquid solution and again with the small accurate proportioning pumps that are available, it is highly recommended that the sodium hypochlorite be fed neat.

Of course, quite a number of other chemicals are used in the water treatment industry and we will comment individually on the following:

Powered Activated Carbon: PAC slurries readily and can be educted or pumped fairly readily. The problem with PAC is its extreme black dustiness. Suggestions were made to use a bayonet fill line for a slurry tank and impale a bag of PAC on the bayonet thus slurrying the PAC as the tank is being filled. The best system of all is likely one like at Elk Point, which is totally enclosed, no dust can escape at all, with a side bag gate.

Alum: Alum is very soluble and there are no problems with feeding alum as long as its extreme corrosiveness is taken into account.

Ferric Chloride: Ferric chloride is seldom used in the water treatment industry but it could be used to advantage in that it forms a much heavier floc than alum does. Never use stainless steel with ferric chloride, it will eat it out in no time.

Sulphuric Acid: We seldom ever see a Silactor any more, modern polymers have replaced activated silica almost universally.

Bentonite: Never, to our knowledge, used municipally. It is used widely industrially for silica removal in boiler feed water. It is fed either as a slurry or slaked. Very difficult to slake.

Chlorine Dioxide: Made on site by chlorinating sodium chlorite. Manufacturers of chlorine have plenty of advice on how best to do this.

Permanganate: It is difficultly soluble in cold water, colouring everything in sight. Other than poorly soluble, there are not many problems with permanganate.

Ozone: Consult ozonator suppliers.

Polymers: The liquid cationics are easy to feed. The liquid anionics or nonionics are not bad to feed. Dry polymers are cost effective in large plants, but are very tough to feed. There is so much literature available from polymer manufacturers on recommended feed systems that we will not comment here.

WHAT IS SMOOTHER - PVC OR CONCRETE
A STUDY OF MANNING'S ROUGHNESS COEFFICIENT FOR COMMERCIAL CONCRETE AND PLASTIC PIPES

D. K. May, B.Sc., Civil Engineering
Professor A. W. Peterson, M.Sc., P.Eng.
Professor N. Rajaratnam, Ph.D., E.Eng.
Presented by: M. T. Yakemchuk, P.Eng.
Consolidated Concrete

A series of hydraulic tests on commercially available pipes were conducted at the University of Alberta T. Blench Hydraulics Laboratory. The purpose of the tests was to determine the Manning's roughness coefficient (n) for each pipe for a range of slopes and discharges, within limits set by the self-cleaning velocity used in design. This velocity is generally reported as 2.5 feet per second (0.76 m/s) for pipes flowing full (Bouthillier, 1981). In all cases new pipes were used, flowing partly full with clean water. The study was designed as a comparison between concrete and plastic pipes, tested under similar laboratory conditions. The concrete pipes, manufactured by Consolidated Concrete Limited, were Packerhead type pipes with bell and spigot joints. The plastic pipes were Polyvinyl chloride (PVC) produced by various manufacturers.

Experimental Apparatus

The pipes were installed in a 37 metre (120 foot) long variable slope flume (Figure 1). The 0.9 metre wide by 0.8 metre deep fibreglass lined, wood flume was supported on a steel framework. Twelve 32 mm threaded stainless steel legs supported the steel framework. The legs were turned with a system of gears and chains which allowed the flume to be raised or lowered while maintaining a linear bed profile. The entire flume swivelled on a pin connection at the upstream end. Lateral support for the flume and framework was provided by steel I-beams embedded in the concrete floor of the laboratory. The maximum slope attainable was one percent.

The pipes to be tested were placed in the flume on wood cradles as shown in figure 1. The cradles were designed to fit the width of the flume which, in theory, would provide a straight horizontal alignment. In practice, due to variability in the cradles, some adjustment was necessary to obtain an accurate alignment. The concrete pipes were placed such that each joint was supported by a cradle. The plastic pipes were supported at, and between the joints to prevent vertical deflection.

Three concrete and three plastic pipes were tested. The nominal inside diameters of the concrete pipes were 8, 10, and 15 inches. The inside of the plastic pipes were 8, 10, and 18 inches. A complete listing of the pipes, ASTM specifications, and manufacturers is shown in Appendix A. Concrete pipe sections were supplied with one pressure tapping in the pipe invert and one observation port 180 degrees from the pressure tapping. These were placed near the spigot end of the pipe. The plastic pipes were supplied with a piezometric tap and an observation port at both ends. It was necessary to cut extra observation ports in all the pipes to facilitate flow measurements within the pipes.

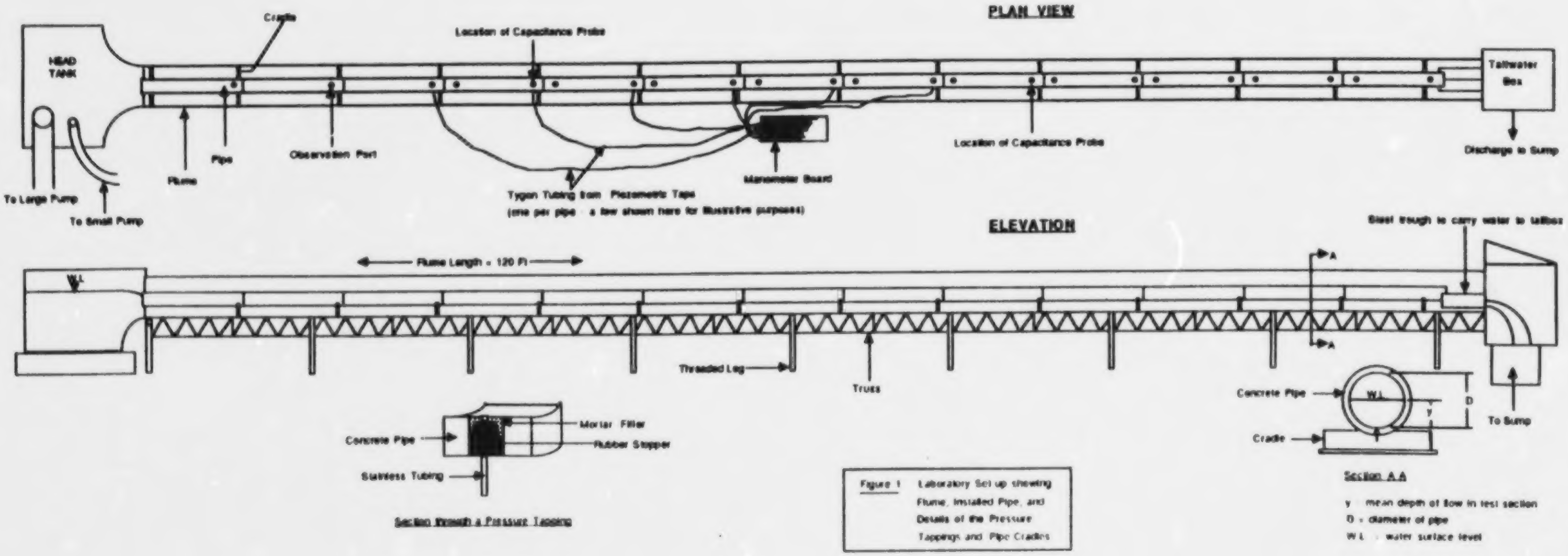

PLAN VIEW
HEAD TANK
Cradle
Location of Capacitance Probe
Tailwater Box
To Large Pump
To Small Pump
Flume
Pipe
Observation Port
Tygon Tubing from Piezometric Taps
(one per pipe - a few shown here for illustrative purposes)
Manometer Board
Location of Capacitance Probe
Discharge to Sump
ELEVATION
Steel trough to carry water to tailbox
W.L.
Flume Length = 120 Ft
A
A
Threaded Leg
Truss
Concrete Pipe
Mortar Filler
Rubber Stopper
Stainless Tubing
Section through a Pressure Tapping
Concrete Pipe
W.L.
y
D
Cradle
To Sump
Section A-A
y : mean depth of flow in test section
D = diameter of pipe
W.L. : water surface level

Figure 1 Laboratory Set up showing Flume, Installed Pipe, and Details of the Pressure Tappings and Pipe Cradles

Two systems, which included pumps, magnetic flow meters, supply lines, and valves supplied water to the flume. For low flows a small pump, three inch supply line, and three inch magnetic flow meter were used to provide between 0 and 10 litres per second. Higher flows were produced by a large pump with a 12 inch supply line and an 8 inch magnetic flow meter. The range of discharge with the two systems was 0 to 260 litres per second. A calibrator was used to set the range of discharges corresponding to the voltage output from the magnetic flow meter so that some multiple of the true discharge in litres per second could be read directly from the voltmeter. Specifications for the pumps, magnetic flow meters, transmitters, and calibrators are given in Appendix B. The supply line discharged into a head tank shown in Figure 1. The head tank was large enough to dissipate the turbulence in the flow discharging from the supply lines and provide a constant head at the pipe inlet.

The concrete pipe entrance conditions were consistent throughout the study. The first bell was inserted into the headwall to be as flush with the headwall as possible. The gap on the inside of the bell for insertion of the spigot was mortared to provide a smooth rounded entrance.

The plastic pipe inlets projected into the head tank. These re-entrant inlets, with greater associated head losses, submerged sooner than the concrete pipe inlets. For large depth to diameter ratios this translated to driving heads well above the top of the pipe. In the case of the ten inch plastic pipe, the head needed for the higher flows exceeded the depth of the head tank, so an aluminium bell-mount entrance was installed on the inlet. This was not a problem with the 18 inch plastic pipe because the limiting factor was discharge rather than driving head. The magnitude of the surface waves, in the test section, was unaffected by the type of entrance condition.

A hogshair mat was placed in front of the inlets to promote turbulence and stimulate the growth of the boundary layer. Table 1 lists the relevant data with respect to the pipe sections, total installed lengths of the pipes, and inlet conditions. The pipe outlets discharged to a tailbox allowing free flow. No tailwater control was used.

Water surface fluctuations were monitored using capacitance depth probes (see Appendix B for specifications) which provided output to a strip chart recorder. The pressure tappings in the bottom of each pipe were connected with Tygon tubing to a sloping manometer board equipped with a metric grid and scale.

Experimental Methods

Placing the pipe sections in the flume was done by hand or with an overhead crane. The pipes were placed on the cradles and joined with the bell ends facing upstream. Rubber gaskets and gasket lubricant were used to seal the joints. Rotation of each pipe section was necessary to ensure that the pressure tapping (piezometer tube) was at the pipe invert. The horizontal alignment was done using stringlines and surveyors level to obtain an alignment which varied by less than one centimetre from the centre line. This is probably more accurate than would be ahcieved during field placement of the pipe.

TABLE 1

Pipe Installation Information

Diameter (in)	Length per Section (M) (ft)	Number of Sections	Total Line Length (M) (ft)	Number of Pressure Taps	Inlet Condition	Outlet Condition
			1. Concrete Pipe			
8	1.28 4.20	29	35.29 115.79	29	Flush Mortared Bell	No Control
10	1.28 4.20	29	35.58 116.73	29	"	"
15	2.47 8.10	15	35.89 117.75	15	"	"
			2. Plastic Pipe			
8	4.13 13.55	9+	37.36 122.60	18	Re-entrant	"
10	4.13 13.55	9+	38.14 125.14	18	Bell Mouth	"
18	4.17 13.68	9+	37.32 122.40	18	Re-entrant	"

Note: Pieces of plastic pipe were cut for the inlets, which explains the plus signs beside the number of pipes used.

The slope of the pipe bed was measured using a surveyors level. Once the zero slope was determined a scale was mounted on the tailwater box and marked for the desired slopes. The slopes used for the study were 0.001, 0.002, 0.0025, 0.0035, 0.004, 0.005, 0.006, 0.008, and 0.010 for each pipe tested. Bed profiles were taken with the level at various slopes and times throughout the study to check the accuracy and consistency of the scale used.

All experiments were conducted in the same manner. The desired flume slope was set using the scale on the tailwater box. The small pump was started and the discharge set to a predetermined level, calculated assuming a value for Manning's n. The manometer tubing was allowed to bleed to flush air from the lines. The discharge reading was then recorded. When the output from the capacitance probes indicated that the water surface had reached an equilibrium depth the manometer readings for the entire line were recorded.

By visual observation of the manometer board, the region of uniform flow was selected. Ideally, this was represented by a linear profile for subcritical flow conditions and increased to the latter two thirds of the profile for supercritical flow. Developing flow was characterized by curvature in the upstream portion of the manometer profile, and was excluded from the test section.

Transition flow conditions (at or near critical flow) presented problems because standing waves developed in the pipe. In these cases the middle third was usually selected for depth measurements.

A point gauge equipped with a vernier scale was used to measure the depth of flow in the pipe within the predetermined uniform flow test section. The water surface and pipe invert were recorded at each observation port within this region yielding at least ten depth measurements for each discharge. The discharge was then recorded again. Each discharge recording consisted of at least ten values read from the voltmeter. In this way an average discharge for the run was obtained from at least twenty individual readings. The discharge was then increased and the process repeated. When the required discharge exceeded the capacity of the small system it was shut down and the valves closed, then the large pump was started and allowed to stabilize. In general, eight discharges were done for each of the nine slopes for each pipe.

The pipe diameters needed for data analysis were measured using an inside micrometer accurate to 1/1000 inch. Both ends of each pipe section were measured twice, with the two measurements taken orthogonally. Appendix C lists the diameter measurements, mean diameters, ranges and standard deviations. Except for the 15 inch concrete pipe, diameter measurements were done after the pipes had been tested.

Analysis

Calculation of Manning's roughness coefficient was done as follows. The depths, measured with the point gauge, were averaged for each run. This was assumed to be the normal depth of flow in the pipe at that slope, diameter, and discharge. Using these four parameters, Manning's n was calculated using the following SI equation:

$$n = \frac{AR^{2/3} S^{1/2}}{Q}$$

Where: n = roughness coefficient
A = area of flow (m^2)
R = hydraulic radius (m)
R = A/P
P = wetted perimeter (m)
Q = discharge (m^3/s)
S = bed slope

For convenience of calculation a computer program was written to calculate the area of flow and the wetted perimeter using subroutines written by Peterson and Howells (1972).

Results

The results of all the tests are illustrated in Figures 2 through 7. Only flow conditions yielding self-cleaning velocities (pipe full) of 2.5 feet per second (0.76 m/s) are included. Using a reference chart of the ratio of hydraulic elements (Bouthillier, 1981, page 41) this converts to about two feet per second (0.61 m/s) at a depth to diameter ratio of 0.5. (Note: the ratio of Manning's n for full flow to n for part-full flow was taken as a variable parameter in this chart.) This criterion was used for each pipe. Milder slopes were eliminated from the analysis.

For low flows (depth to diameter ratios less than 0.25) Manning's n decreased significantly with increasing bed slope. At higher ratios of depth to diameter (0.6 to 1.0) the plots show that the n values gradually converge. This allowed a mean n value to be calculated for all results within the upper range of flows. For convenience a depth to diameter ratio of 0.25 was used to divide the results. Table 2 shows the mean Manning's n values for two categories. Referring to the depth to diameter ratios greater than 0.25, the differences between the n values for the three sizes of concrete pipe are insignificant, allowing a mean Manning's n value of 0.010 to be calculated for three Packerhead concrete pipes.

The eight and ten inch plastic pipes can be grouped together yielding an average Manning's n coefficient of 0.0088. The eighteen inch Siro-loc plastic line (see plate 6) has a slightly higher average n value of 0.0091. Standard references (see Chow, 1959, page 10, and Henderson, 1966, page 99) use only three decimal places and, at most, two significant figures when reporting values of Manning's n. This seems advisable when the uncertainties in measurement are considered. Therefore, a mean n value of 0.009 can be used for all the plastic pipes tested. For lower depth to diameter ratios the coefficients should be altered as shown in Table 2.

Discussion

The parameters of interest when calculating Manning's friction coefficient are slope, discharge, and cross sectional flow geometry (in this case a function of mean depth and pipe diameter). A brief discussion of the experimental uncertainties involved in measurement of these parameters is important to justify the results.

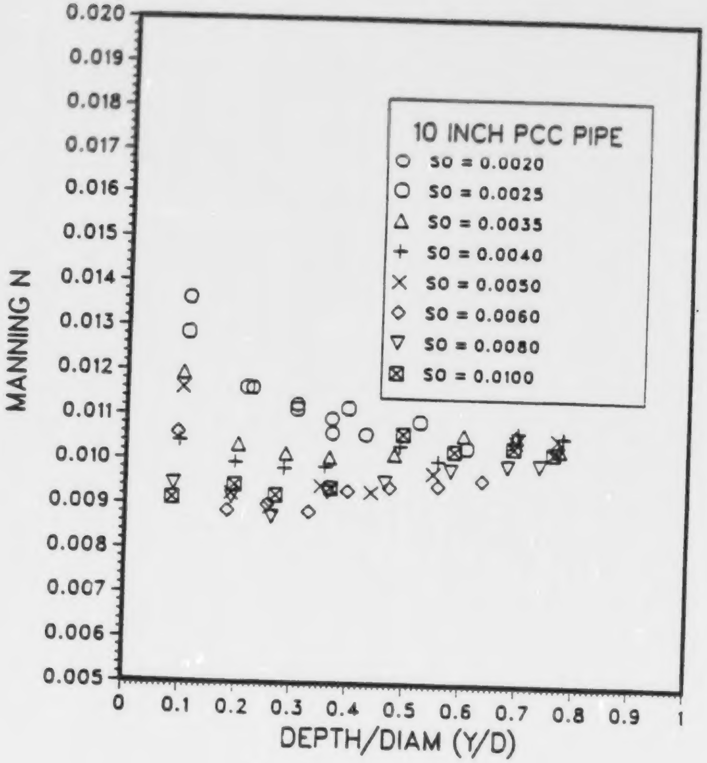


Figure 3 : Plot of Manning's n versus y/D for the 10 inch concrete pipe, at various bed slopes (SO).

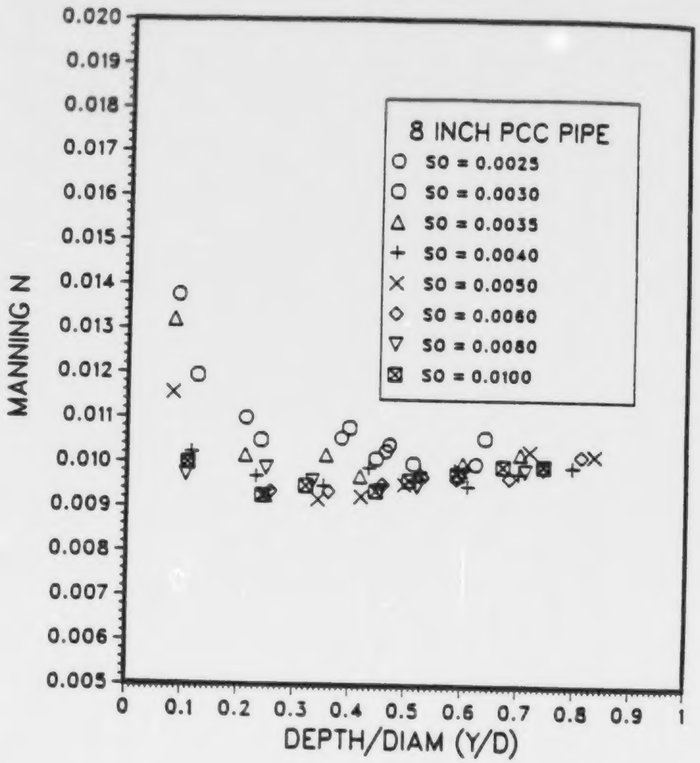


Figure 2 : Plot of Manning's n versus the depth diameter ratio (y/D) for the 8 inch concrete pipe, at various bed slopes (SO = bed slope).

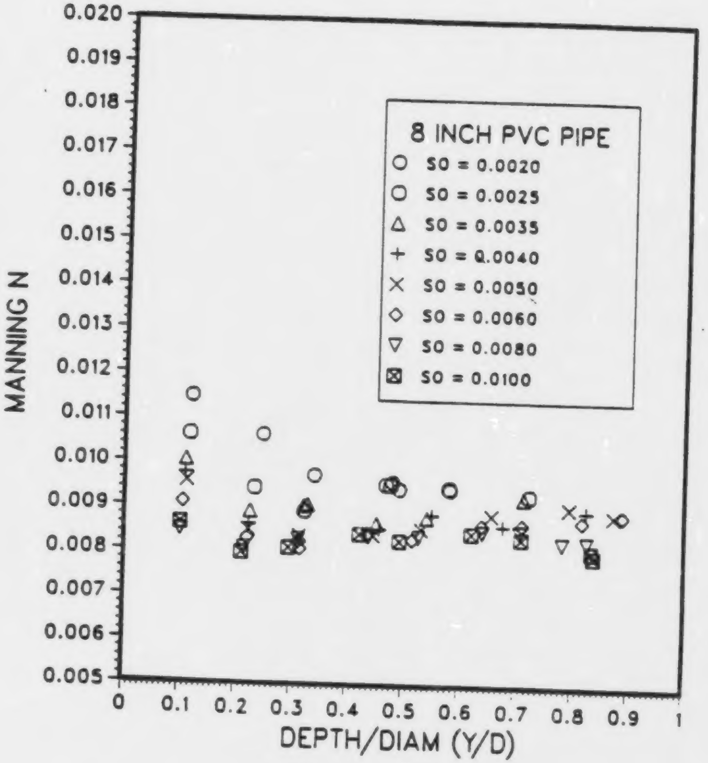


Figure 5 : Plot of Manning's n versus y/D for the 8 inch plastic pipe, for various slopes (SO).

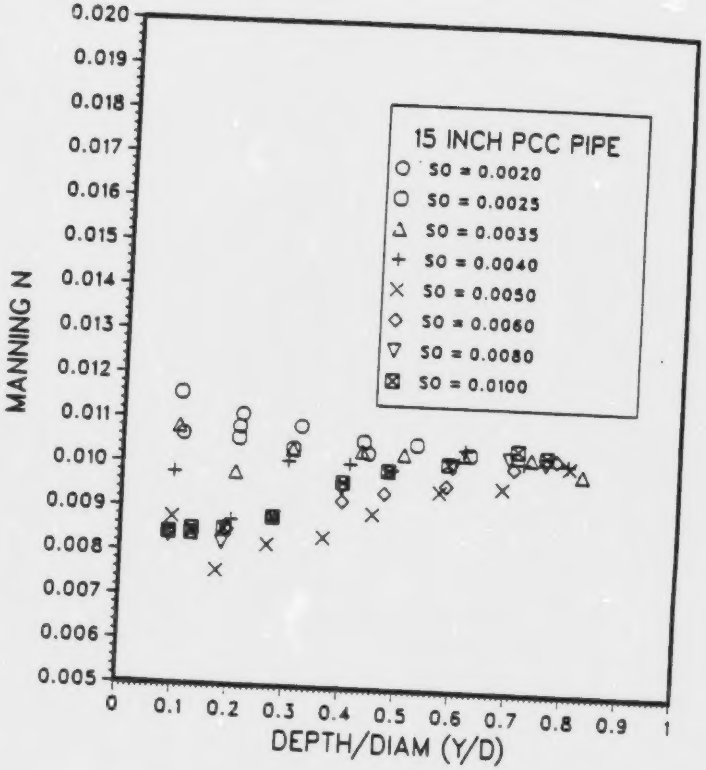


Figure 4 : Plot of Manning's n versus y/D for the 15 inch concrete pipe, at various bed slopes (SO).

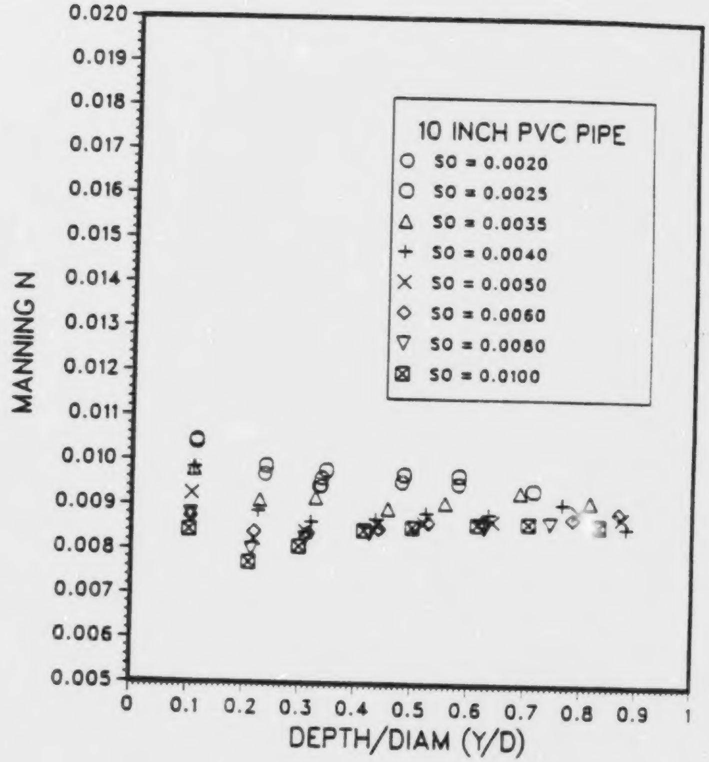


Figure 6 : Plot of Manning's n versus y/D for the 10 inch plastic pipe, for various slopes (SO).

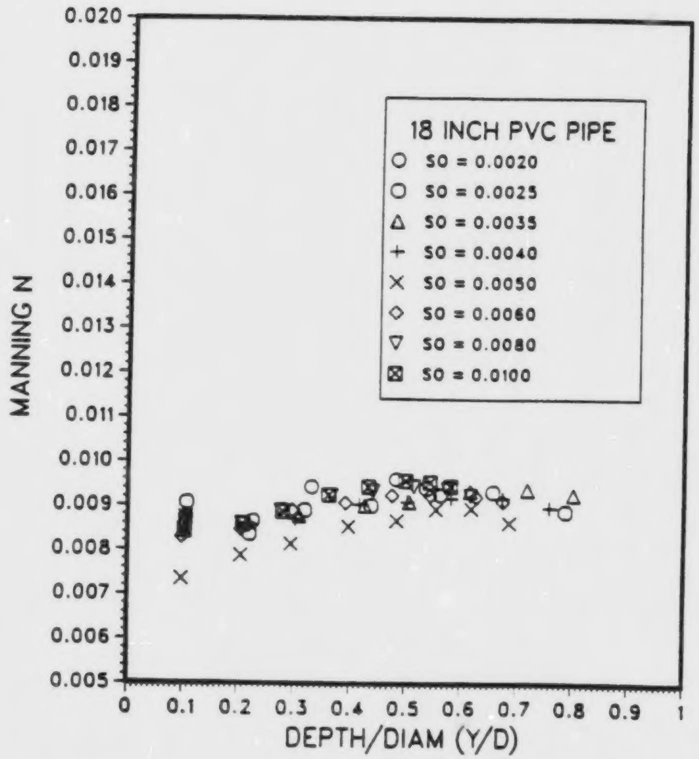


Figure 7 : Plot of Manning's n versus y/D for the 18 inch plastic pipe, at various bed slopes (SO).

TABLE 2

Mean Values of Manning's n for All Pipes and y/D Ratios

Depth-Diameter (y/D) Ratios Greater than 0.25

	Concrete Pipe			Plastic Pipe		
	8 inch	10 inch	15 inch	8 inch	10 inch	15 inch
Manning's n Values (samples size)	0.0098 (44)	0.0100 (45)	0.0099 (42)	0.0087 (47)	0.0089 (44)	0.0091 (44)

Depth-Diameter Ratios less than 0.25

	Concrete Pipe			Plastic Pipe		
	8 inch	10 inch	15 inch	8 inch	10 inch	15 inch
Manning's n Values (samples size)	0.0107 (15)	0.0100 (16)	0.0094 (18)	0.0092 (16)	0.0090 (18)	0.0085 (19)

Overall Averages

	Concrete Pipe	Plastic Pipe
y/D > 0.25	0.0099	0.0089
y/D < 0.25	0.0102	0.0089

Slope

Uncertainties in the bed slope were within five percent in all but the most mild slopes. Considerable care was taken to select regions of flow in the pipe where the slope of the water surface, as indicated by the manometer profile, was linear. It was assumed that, in this region, the slope of the water surface was equal to the bed slope. However, tests done at mild slopes with high depth to diameter ratios were affected by drawdown of the water surface profile. Backwater profiles were calculated for all tests done at mild slopes. A test length of one half the flume length was used. If the average centerline depth in the pipe at the test length was at least 95 percent of the normal depth then the data was included. If not, it was discarded. The careful use of tailwater control would have alleviated this problem and is recommended for any future tests of this nature. A trial and error approach must be used with tailwater control until the slope of the water surface profile, as indicated by the manometer board, equals the bed slope exactly.

Discharge

The listed accuracy of the magnetic flow meters was one percent of the full scale output. One percent of the full scale reading for the small magnetic flow meter was 0.1 litres per second, and 2.5 litres per second for the large meter. In practice, the discharge meters performed within finer tolerances. Both the small and large magnetic flow meters were calibrated. The resulting accuracies were found to be 0.21 percent of the full scale reading for the small meter and 0.20 percent of the full scale value for the large meter.

Depth

The experiments were conducted such that the depth of uniform flow was obtained from the maximum number of readings possible. Transition flow conditions presented a problem due to standing waves on the surface profile with amplitudes up to fifty millimetres, in extreme cases. The waves were generated at the entrance and by the joints between each pipe section. Al the pipes exhibited inlet waves of the same relative shape and magnitude, regardless of the type of entrance condition used. The large undular waves at the inlet tended to dampen as they proceeded downstream. Within the test sections it appeared that the surface waves originated mainly from the joints. At mild slopes (0 to 0.003) and steep slopes (0.006 to 0.010) the waves were much less pronounced. Despite the averaging process, which would tend to dampen the effects of surface waves on the calculations, the waves may explain some of the scatter in Manning's n found for transition conditions.

Diameter

The most noticeable variations in diameter were caused by the following:

1. Out-of-roundness (five millimetres between orthogonal measurements observed in the plastic pipe) and,
2. a slight decrease in the inside diameter at the bell end of all the concrete pipes (usually in the order of a few millimetres).

These variations did not produce significant error in the results compared to previous parameters. Much more important were the noticeable effects of the pipe joints which initiated the formation of surface waves in the pipe.

Percentage error was calculated for each value of Manning's n. Any error greater than 25 percent was discarded. For practical purposes an error of 10 percent can be used. This translates to two significant figures, at most, when reporting values of Manning's n which agrees with references mentioned previously.

The results are interesting because they demonstrate that, despite the differences in the surface textures of the two types of pipes tested, the average Manning's roughness coefficients are comparable.

The results are in agreement with other laboratory studies. Neale and Price (1964) reported an average Manning's n value of 0.009 for clean water, open channel flow in 8 and 12 inch PVC pipes. Bloodgood and Bell (1961) found an average Manning's n for open channel flow in cement-asbestos pipe of 0.0109. Straub et al (1960) reported a Manning's roughness coefficient of 0.106 for 24 inch tamped concrete pipe with good joints, and values as low as 0.009 for cast concrete pipe (pipes flowing full).

Standard references usually show a greater variation between the two types of pipes when listing recommended design values of Manning's n roughness coefficient for design of 0.012 for concrete pipe (steel trowelled) and 0.010 for plastic pipe. Chow (1959) recommends 0.013 for concrete culverts and 0.010 for non-metals such as glass and lucite.

Jeppson (1976, page 41) lists n values of 0.008 for PVC pipe and 0.016 for concrete pipe (flowing full).

The design values reflect factors of safety, built-in to the roughness coefficient to account for variables such as poor alignment, grade control, and aging. But there is a discrepency between the factors of safety applied to the two materials. In general the roughness coefficient used for the design of plastic sewers is within ten percent of the laboratory value, while the design coefficients used for concrete sewers are between ten and sixty percent higher than laboratory results. Perkins and Gardiner (1982) tested slime build-up in concrete and plastic sewer pipes which provided some insight to the problem. They concluded that "the pipe material has some influence on the amount of slime present and therefore on the hydraulic roughness". However, field investigations comparing modern concrete and plastic sewer installations are scarce and more should be done in the future to help clarify this situation.

Conclusions

Based on the results of the tests performed on the six pipes the following values of Manning's n have been determined for depth to diameter ratios greater than 0.25:

1. Packerhead concrete pipes (8, 10, and 15 inch): n = 0.010
2. Plastic (PVC) sewer main pipes (8 and 10 inch): n = 0.009
3. Plastic (PVC) Spiro-loc pipe (18 inch) n = 0.009

In other words, the plastic pipe tested will supply, on average, ten percent more discharge than the concrete pipe. Keep in mind that these results reflect only the inherent differences in wall roughness and joint effects under laboratory conditions using new pipe. In practise, other factors are important such as differences in aging characteristics between the two materials, differences in slime build-up in the pipes, and differences in the workmanship due to the material properties of two types of pipe. The number of manholes, tees, bends, and junctions will all influence the hydraulic grade line and the overall energy losses in a system.

Recommendations

1. Based on error analysis and assumptions involved in formulating Manning's equation, Manning's roughness coefficient should be reported to three decimal places and, at most, two significant figures.

2. The careful use of tailwater control is recommended for studies of this nature to obtain the widest possible range of flow conditions when the length of the testing facility is limited (as it usually is in the laboratory).

3. Field investigations are recommended to clarify design values of Manning's roughness coefficient for modern concrete and plastic sewers.

Appendix A : Pipe Specifications and Manufacturers

Pipe	Nominal Diameter (inches)	ASTM Standards	Tradename	Manufacturer
(1) **Concrete**				
NR	8	C-14-III	Packerhead	Consolidated Concrete
NR	10	C-14-III	"	"
R	15	C-76-IV	"	"
(2) **Plastic**				
PVC	8	3034	SDR-35 PSM	Scepter
PVC	10	D-3034	Cobra 1120 SDR-35 PSM	Grandview
PVC	18	F794	Perma-loc PS 320 sewer	Manville

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Key :

NR : nonreinforced
R : reinforced
PVC : polyvinyl chloride
PSM : plastic sewer main

Appendix B : Specifications for Pumps and Meters

(1) Pumps

Range of Discharge

Goulds Centrifugal Pump
0 - 10 l/sec
Index : 624 34322
Model : 3643
Size : 2.5

Motor : Marathon 3 Phase
Model : CC 182TTDR8619BAV
Frame : 182T
Type : YDRBCZ
@ 60 HZ : S.F. = 1.15
Volts = 208-220/440
Amps = 12.8/6.4
Full Load RPM = 3465

Fairbanks-Morse Figure 6310 Propeller Pump
10 - 250 l/sec
Serial no. : P2B4466
Pump Size : 14
Stages : 1
Propellor : B-1304-A
RPM : 1160

Motor : Induction Type KZKV
Frame : 365UP
Number : F367105
Specification : T1032-1
@ 60 HZ : S.F. = 1.15
25 H.P.
Full load RPM = 1165

(2) Magnetic Flow Meters, Transmitters, and Calibrators

Foxboro Magnetic Flow Meters

Small System

Type : 1803 SANS-CA
0 -10 l/sec
Size : 3 inch
Serial : 476542
Liner : Neoprene
Material : 304 S.S.
Electrode : 316 S.S.
Rating : @ 60 HZ : 2.08 Amps
115 Volts
25 Watts
Series Connection

Output : 0.01519 mV per USGPM

Appendix B : Specifications for Pumps and Meters

Large System

Range of Discharge

0 - 250 l/sec

Type : 1808 SANS-BA
Size : 8 inch
Serial : M-84925
Liner : Neoprene
Material : 304 S.S.
Electrode : 316 S.S.
Rating : @ 60 HZ : 12.4 Amps
115 Volts
225 Watts
Parallel Connection

Output : 0.003924 mV per USGPM

Foxboro Magnetic Flow Transmitter

Model : E96R-VA ST.C
Serial : M-374650 C
Frequency : 60 Hz
Input : 0 - 5 mV
Output : 0 - 10 VDC

Foxboro Magnetic Flow Calibrator

Model : 8120-6
Order no. : 74N-13156-1
Serial : 3051265
Volts : 118 / 236
Frequency : 60 Hz
Volts*Amps : 1.5
Phase Band : E

Appendix C : Inside Diameter Measurements of Test Pipes

Note : 0.500 inches must be added to all measurements to obtain the true pipe diameter. Quarter inch steel ball bearings were attached to the ends of the micrometer with brass sleeves to protect the machined surfaces. Each measurement in the pair was taken orthogonally to the other and each pair represents one end of one pipe.

(1) Concrete Pipe (measurements in inches)

	8 Inch Diameter		10 Inch Diameter		15 Inch Diameter	
	Spigot End	Bell End	Spigot End	Bell End	Spigot End	Bell End
	7.518	7.500	9.566	9.504	14.293	14.568
	7.527	7.495	9.579	9.530	14.369	14.546
	7.524	7.493	9.564	9.470	14.406	14.545
	7.533	7.417	9.528	9.484	14.411	14.542
	7.501	7.463	9.554	9.534	14.348	14.558
	7.521	7.479	9.581	9.515	14.399	14.481
	7.518	7.455	9.567	9.539	14.387	14.567
	7.520	7.454	9.558	9.522	14.447	14.600
	7.519	7.455	9.578	9.443	14.458	14.474
	7.511	7.469	9.582	9.428	14.432	14.604
	7.501	7.431	9.566	9.503		
	7.512	7.428	9.585	9.534		
	7.505	7.464	9.581	9.422		
	7.504	7.440	9.590	9.426		
	7.480	7.471	9.578	9.545		
	7.513	7.495	9.566	9.538		
	7.540	7.456	9.574	9.540		
	7.514	7.480	9.573	9.541		
	7.531	7.420	9.559	9.518		
	7.522	7.415	9.531	9.467		
Mean	7.516	7.459	9.568	9.500	14.395	14.549
Plus 0.5 in.	8.016	7.959	10.068	10.000	14.895	15.049
Overall (in.)	7.988		10.034		14.972	
Millimetres	202.88		254.87		380.28	
Std. Dev.(in.)	0.0134	0.0271	0.0176	0.0428	0.0492	0.0431
Range : Max:	8.033	8.000	10.090	10.045	14.958	15.104
(in.) Min:	7.980	7.915	10.028	9.922	14.793	14.981

Appendix C : Inside Diameter Measurements of Test Pipes

(2) Plastic Pipe (measured in inches)

	8 Inch Diameter		10 Inch Diameter		18 Inch Diameter	
	Spigot End	Bell End	Spigot End	Bell End	Spigot End	Bell End
	7.413	7.318	9.339	9.287	17.124	17.162
	7.368	7.364	9.372	9.289	17.202	17.149
	7.253	7.334	9.416	9.324	17.183	17.248
	7.424	7.366	9.290	9.343	17.175	17.061
	7.300	7.389	9.314	9.304	17.075	17.170
	7.433	7.320	9.397	9.285	17.250	17.245
	7.407	7.320	9.317	9.317	17.263	17.155
	7.302	7.335	9.366	9.364	17.090	17.210
	7.358	7.337	9.300	9.286	17.124	17.131
	7.328	7.354	9.376	9.302	17.192	17.199
	7.385	7.382	9.355	9.325	17.125	17.070
	7.350	7.394	9.355	9.337	17.235	17.191
	7.306	7.413	9.337	9.366	17.146	17.155
	7.415	7.304	9.361	9.337	17.161	17.170
	7.268	7.314	9.341	9.304	17.110	17.246
	7.464	7.396	9.365	9.329	17.210	17.069
	7.311	7.356	9.312	9.319	17.203	17.132
	7.393	7.385	9.344	9.377	17.081	17.172
	7.370	7.313	9.343	9.385	17.180	17.106
	7.374	7.397	9.319	9.321	17.140	17.295
	7.310	7.363	9.283	9.320	17.289	17.211
	7.393	7.333	9.382	9.380	17.137	17.207
	7.395	7.397	9.368	9.303	17.163	17.198
	7.335	7.353	9.305	9.292	17.173	17.137
Mean	7.361	7.356	9.344	9.325	17.168	17.170
Plus 0.5 in.	7.861	7.856	9.844	9.825	17.668	17.670
Overall (in)	7.858		9.834		17.669	
Millimetres	199.60		249.79		448.80	
Std. Dev.(in.)	0.0548	0.0327	0.0341	0.0310	0.0566	0.0646
Range : max:	7.964	7.913	9.916	9.885	17.789	17.795
(in.) min:	7.753	7.804	9.783	9.785	17.581	17.561

A NEW TURBINE AERATOR FOR TREATING WASTEWATERS

C. Guarnaschelli and K. G. Elstone

Introduction

During the past decade aeration equipment has been evaluated under a variety of test conditions by many laboratories and various manufacturers. The various aeration systems available are usually grouped into 3 basic categories: surface aerators; diffusers, typically bottom mounted and compressor driven; and submerged turbines, utilizing a compressor/rotor combination. Recently a new group of aeration devices has emerged that can be broadly described as subsurface air inducers. We will address the development, testing and application of one such device described as a rotary, centrifugally pumped air induction system. A brief theoretical background will be presented followed by testing procedures and results. Finally, the most important practical aspects will be discussed and summarized.

Comprehensive reviews (e.g., CPAR 542-1) have analyzed in detail both the theoretical aspects of aeration and have listed the shortcomings of the available systems. In general, all authors have agreed on (1) the use of clean water for non-steady-state aeration tests; (2) the necessity of a thorough investigation of the limited mixing regime of surface aerators; (3) the need for more research on the power density presently either used or assumed; and (4) the necessity to provide adequate maintenance for reliability of operation. In the present investigation, all of these points have been taken into consideration for the optimization of oxygen transfer efficiencies with particular emphasis placed on testing procedures, methods of analysis and scale-up of test results.

Theoretical Background

The most accepted theory used to explain the oxygen transfer at the gas/liquid interface is the film theory proposed by Whitman (2). In this model, a thin film is imagined at the surface of the liquid adjacent to the gas phase. Here molecular diffusion alone is responsible for the drop in oxygen concentration between the gas phase and the bulk of the liquid phase. The basic equation that describes this process is:

$$dm/dt = D/z\ (Cs - Ct)$$

where dm/dt is the rate of mass transfer in a unit time, D the diffusivity, z the film thickness, Cs the saturation concentration of oxygen, and Ct the oxygen concentration in the liquid at time t. Unfortunately in practice it is not possible to measure the diffusivity and the film thickness, therefore an overall mass transfer coefficient, KLa20 which includes the interfacial surface area, is measured. It is this coefficient that best describes the performance of the aeration equipment. The major shortcomings, correction factors and interferences are:

1. Atmospheric pressure;
2. Partial pressure of oxygen;
3. Liquid temperature;
4. Presence of dissolved solids;
5. Presence of suspended solids;
6. Presence of surfactants;
7. Fluid turbulence; and,
8. Basin geometry and power densities.

Variations in atmospheric pressure influence the partial pressure of oxygen in air and, therefore, determine the saturation concentration of oxygen in water.

Water temperature affects the resistance of the liquid film in terms of viscosity and diffusivity. The overall exponential equation used to extrapolate and calculated KLa value at temperature T to 20°C has the following form:

$$KLa20 = KLaT\ (1.024)\ \exp(20-T)$$

where 1.024 is the average temperature coefficient recommended by the Water Pollution Control Federation, Manual of Practice No. 5.

The remaining factors are more difficult to analyze individually and are commonly grouped into an alpha and a beta correction factor. The alpha correction factor, which is the ratio of (KLa wastewater) to (KLa pure water), varies between 0.85 and 1.15 to account for the presence of dissolved solids (electrolytes, viscosity), total solids and surfactants. Test results in the case of total solids and surfactants are very controversial. The beta correction factor, or the ratio between [Csw(T,P)Wastewater] and [Css(T,P) Pure Water], incorporates oxygen solubility variables like dissolved solids and organic substances by comparing the saturation concentrations at the same temperature and pressure. Typical values for domestic water and river water are 0.95 and 1.00 respectively. Fluid turbulence, basin geometry and power densities are the only macro-variables under the control of the experimenter.

Factors Affecting Gas Dispersion in the Liquid Phase

Any system which involves liquid/gas mixing is affected by two basic mechanisms: (1) mass transfer and (2) chemical reactivity. For effective mass transfer, the experimenter must consider diffusion rates through the gas/film interface and bulk mixing. In the case of chemical reactivity a major consideration should go to product formation and/or adsorption in the bulk phase. In the specific case of aeration, the rate controlling steps are: (1) the mass transfer at the gas/film interface and (2) the diffusion within the bulk of the liquid phase. Both rates are enhanced by mixing.

To achieve homogeneity, it is conceivable that the most appropriate mixing regime is turbulent rather than laminar. Turbulence provides more uniform mixing, creates zones of high shear and reduces coalescence of the rising bubbles. All of these factors together with the volume expansion of the ascending bubbles enhance the oxygen transfer efficiency.

Theoretically, the power required for mixing is proportional to the flow and the head or, mathematically, proportional to the speed of rotation to the third power and the diameter to the fifth power:

$$P = K\,N^{3}\,D^{5}$$

where K is the proportionality constant. This basic equation tells us that at constant power, a large diameter, slow moving impeller produces a large flow and low shear (laminar flow) whereas a small diameter, fast moving impeller creates a low flow and high shear (turbulent flow).

The impellers investigated in this study are specifically designed to take advantage of the high speed and high shear without sacrificing the minimum flow required for mixing.

Theoretical Aspects of Centrifugally Pumped Air Induction Systems

The entire oxygen transfer process consists of optimizing the transfer of oxygen to a large body of water. Because homogeneous transfer throughout the entire body is difficult to achieve, two separate functions are identified. Firstly, oxygen must be made available to a sub-zone of the entire water body for direct transfer, and secondly this sub-zone should be distributed or mixed throughout the body to achieve homogeneity. The replacement of the highly saturated sub-zone with water of lower oxygen concentration is also important for the enhancement of the transfer process within the sub-zone.

In general, subsurface aeration systems have handled the two processes separately providing power to a compressor for the supply of oxygen to the oxygen enriched sub-zone to bulk mixing process. The air induction mechanism of the centrifugally pumped air induction system utilizes the flow produced by the mixing impeller to draw the air into the sub-zone by venturi induction within the mixing impeller. The combination of the two processes unifies the input reducing the overall power consumption.

The centrifugally pumped air induction impeller has been designed to take full advantage of the aspects discussed previously. The rapid rotation of the impeller provides several transfer enhancement mechanisms. To begin with high directional turbulence is produced in the high oxygenation sub-zone. The directionality of this turbulent flow is important because, as kinetic energy is dissipated, a directional laminar flow is produced which carries the highly oxygenated water from the sub-zone into the main body of the basin. The high shear inherent within the turbulent flow regime has also been demonstrated to enhance oxygen transfer. Secondly, shearing of the induced air stream by the impeller vane edges produces many small bubbles of high total surface area. A direct correlation between bubble size and oxygen transfer has also been well documented; this is the basis behind fine bubble diffusion. In the case of the centrifugally pumped air induction system the greater the rotational speed the smaller the bubble size produced. Finally, the centrifugally pumped system's inherent efficiency allows the air induction to occur at depths of up to 16 feet as opposed to depths of 5 - 8 feet for axially pumped induction systems.

This air injection at depth provides for a long bubble "hang time" which further enhances the oxygen transfer process. All of these mechanisms are essential to the oxygen transfer prosess and were taken into sonciderationin the design of the centrifugally pumped air induction system.

Test Procedures

The method adopted to test the efficiency of the various impellers is the one outlined in the Manual of Practice No. 5 of the Water Pollution Control Federation entitled "Aeration in Wastewater Treatment". It consists of using tap clean tap water in a clean tank, removing the dissolved oxygen using sodium sulphite and a cobalt catalyst, and by measuring intermittently or continuously the oxygen uptake with the aerator in operation. The oxygen transfer coefficient is then calculated from the slope of the semi-log plot of oxygen deficiency versus time (Fig. 1).

All tests were carried out in plastic tanks, 0.6 x 0.6 x 1.2 m for the smaller impellers and 1.2 m diameter x 1.3 m for the larger impellers. Oxygen concentrations were measured with a Portable Oxygen Meter (Model 57) manufactured by Yellow Springs Instruments Co. Power consumptions were measured with an Hioki Model 3303 Power Meter.

Dissolved oxygen gradients will be present in the basin if the liquid is not thoroughly mixed. To avoid this limitation an assessment of the concentration gradient within the tank was initiated using the oxygen probe. The turbulent flow of the impeller was always adjusted to provide the necessary degree of mixing required to create an homogeneous system well within the response time of the oxygen probe (Fig.2).

Measurements of the oxygen concentration was performed polarographically rather than using the Winkler chemical method in order to minimize chemical effects and interferences associated with sulphite and cobalt chloride concentrations. To minimize these effects, a reduction in cobalt chloride concentration to 0.05 mg/L or lower has been suggested, however, up to 2 mg/L were used in some of these tests because, if an insufficient quantity of catalyst is used, the oxygenation reaction will not go to completion and the unreacted sulphite will cause an interference which will result in a lower oxygen transfer coefficient. This effect has concerned manufacturers because they feel that insufficient catalytic action detracts from their equipment performance. The only disadvantage is the probe inherent response time. Fortunately, this response time can be mathematically predicted and no correction is required when Kp is less than ten times the value of KLa (Fig.2).

Evaluation and Analysis of Test Data

Experimental data have been analyzed using the log deficit method shown in Fig.1. Using this method, if the saturation concentration is correct, a straight line can be drawn through the plotted data. As indicated in the test procedures outlined by the WPCF, only the points between 10 and 70 percent saturation were used to calculate the oxygen

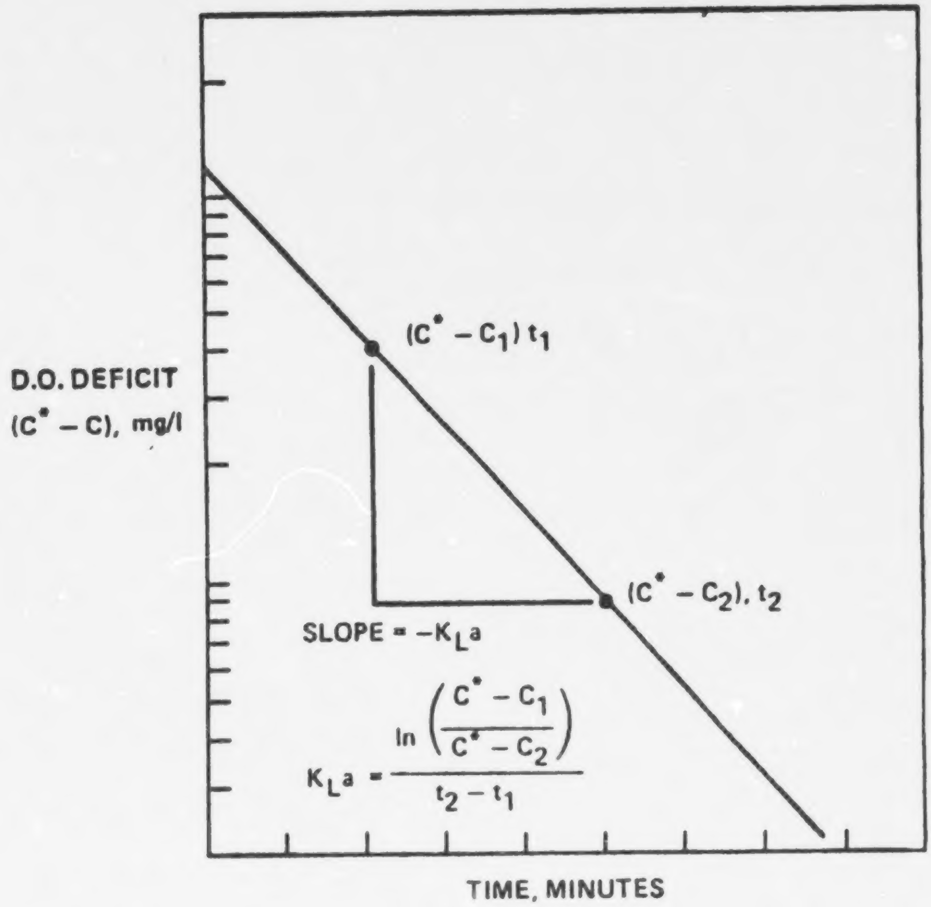


Fig. 1 - DISSOLVED OXYGEN DEFICIT VERSUS TIME

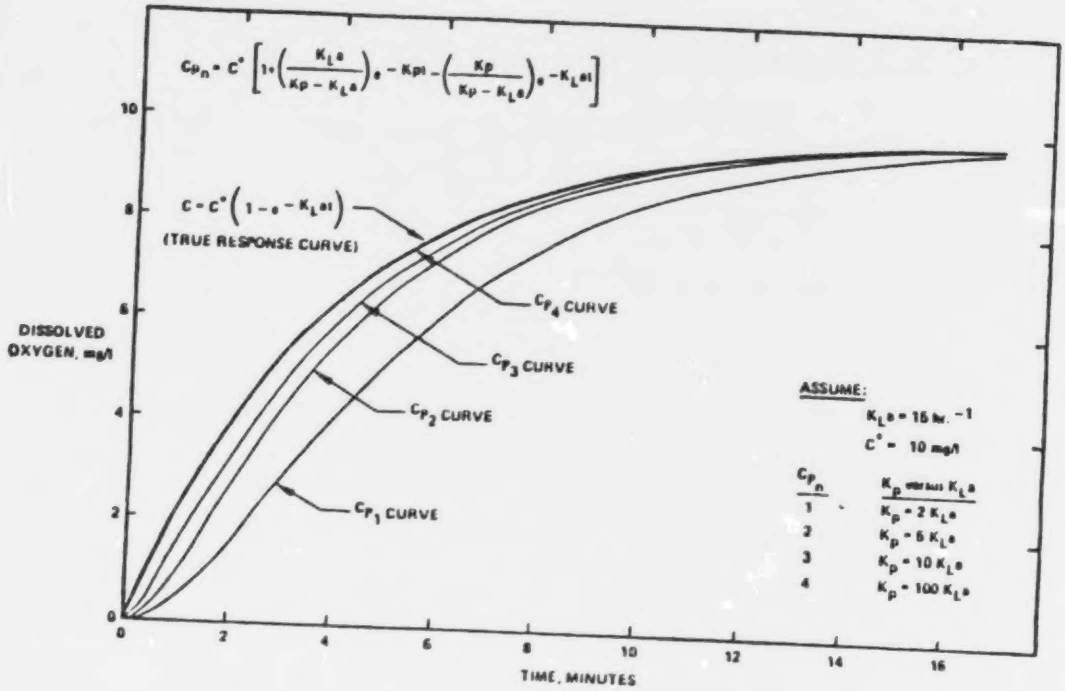


Fig. 2 - EFFECT OF Kp ON RESPONSE CURVE

transfer coefficient. All tests were recorded on a standard form where the linearity of the plot could be immediately verified. Slight variations in the calculated saturated oxygen concentration are attributed to the response time of the oxygen probe and the inherent difficulty in determining the precise moment when the oxygen uptake by the sulphite has ended. In addition, variations in the oxygen saturation concentration were considered and the suggested 0.25 tank depth was selected for oxygen probe determinations (Fig. 3).

Laboratory tests using different impeller configurations produced a linear relationship between the Kla20 values and the tip speed of the impeller blades. From the replicate tests it can be seen that conventional Kla20 values can be as high as 150 for tangential velocities of 450 m/min. In practice such a high impeller speed is not necessary but it is comforting to know that, if required, more oxygen can be introduced in the system to compensate for unusual oxygen requirements by the process using the same impeller.

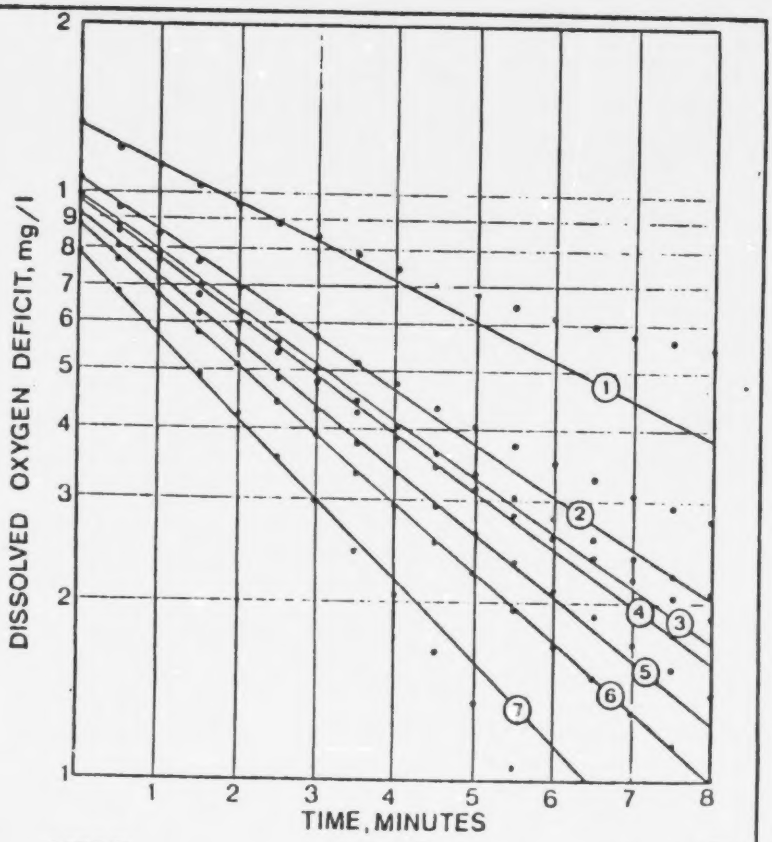
Rates of Oxygen Transfer

Measurements of oxygen transfer rates are strongly dependent on the mixing regime developed in the basin, are lengthy, laborious, and require careful interpretation. To expedite experimental testing of new impeller configurations a combination of oxygen transfer rates, Kla20, volumes of air induced and power consumption at different speeds was adopted. It is also customary to describe oxygen transfer rates of an aerator in terms of volumes of air transferred by each unit. The oxygen transfer rate of commercial units running at depths less than five feet varies between one and two pounds/hour for an input between 20 and 50 cubic feet of air/minute. This means that even at 20 SCFM (1200 SCFM for an oxygen content of 22.4 lb.) the maximum oxygen transfer efficiency is 9% dropping to 3.6% for 50 SCFM. In our tests the transfer efficiency of our 22 cm impeller starts at 18% and reaches 33% at normal operating speeds (Table 1).

TABLE 1

Oxygen Transfer Efficiency

Impeller Type (cm)	Tang. Vel. m/min	Kla20	Basin Volume cu. ft.	$\#O_2$/hr	SCFH	Air Flow $\#O_2$/hr	Oxygen Transfer % Effic.
20.4	384	12.2	48	0.34	100	1.9	18
20.4	449	20.6	48	0.57	140	2.6	20
20.4	481	34.6	48	0.95	160	3.0	32
20.4	513	42.4	48	1.16	185	3.5	33
20.4	577	50.1	48	1.38	230	4.4	31



MODEL	$K_La(28^o)$	$C_{se}(28^oC)$
1. Bottom Saturation	9.3 hr^{-1}	13.3 mg/l
2. Mid-Depth	12.3 ″	10.6 ″
3. Mid-Depth Corrected	13.2 ″	9.9 ″
4. Log Mean	13.8 ″	9.7 ″
5. 0.25 Submergence	15.0 ″	9.2 ″
6. Best Fit	16.3 ″	8.8 ″
7. Suface Saturation	19.1 hr^{-1}	7.9 mg/l

Fig. 3 - K_La PLOTS FOR VARIOUS C_{se} MODELS

In Europe, at Nola, a 22 cm Aluminium/Magnesium impeller was tested in a 100 cubic metre basin at 700 RPM with a 3.5 HP gear motor. The resulting Kla20 was 5.9 for an effective oxygen transfer of 1.5 kg of oxygen/HP/hr. In our laboratory it was found that there is a linear relationship between volume of induced air and tip speed or RPM suggesting that, apart from other considerations, the appropriate oxygen requirement to satisfy a particular process can be selected simply by choosing the appropriate speed required to induce the necessary volume of air into the bulk of the liquid.

In conventional oxygen transfer terms, to date, the centrifugally pumped air induction system has produced transfer rates of 3.5 lbs O2/HPhr. This value is competitive with present highly developed conventional systems. As the technology behind air induction systems progresses further the efficiencies produced by optimal impeller configurations are expected to provide significant increases in these transfer rates. In addition to this additional benefits such as reliability and versatility further enhance the economic viability of these systems.

Field Applications

In the field, four 7.5 HP V belt units have been operating intermittently over the last two years at the Gold Bar Wastewater Treatment Plant in Edmonton, Alberta. In addition to this a 7.5 belt and a direct drive unit have been working in a winery at Domain Chandon in California and a small test unit was used successfully at Kaiser Resources in the biological treatment of coke oven effluent until the plant was shut down.

The City of Edmonton's Clover Bar sludge storage lagoon uses the aerators to remove ammonia nitrogen from the industrial effluent prior to discharge. The daily flow to the treatment pond in approximately 2.2 M/L per day averaging 960 ppm of ammonia nitrogen. The first test unit installed removed an average of 10% of the nitrogen with subsequent units adding and exceeding a 10% average removal for an overall removal of approximately 50% at impeller speeds in the order of 1200 RPM (Table 2). Presently studies are under way to winterize the operation in order to achieve acceptable removal rates of ammonia nitrogen throughout the year.

Initial design difficulties were identified and it was most important to address these difficulties before they become operational problems. At the lagoons in Edmonton an undesirable "salt" deposition on the high surface energy area of the impeller plugged the air intake holes. This was remedied by coating the entire impeller with abrasion resistant urethane, a coating which also provides a very good degree of chemical protection against corrosion. In the same plant fibrous solids within the application basin accumulated around the blades and finally plugged the impeller intake. This problem was resolved by attaching a dynamic screen to the impeller. This screen has long transverse openings which allow for minimal resistance to water intake.

AMMONIA - NITROGEN CONCENTRATION

TABLE 2

Sample Delivery Date	Clover Bar Effluent		Capital Regional								Bremner Effluent	
			Raw		Primary Effl.		Final Effluent		Dig. #2 Overflow			
	G Bar ID	mg/L	ID#	M/L	ID#	mg/L	ID#	mg/L	ID#	mg/L	ID#	mg/L
June 09	1426	490.2	1432	25.9	1433	40.4	1434	≤0.3	-	-	-	97.8
June 10	-	-	1435	48.0	1436	59.6	1437	≤0.3	-	-	-	107.4
June 11	1470	551.4	1466	50.4	1467	60.6	1468	≤0.3	1469	1098.4	-	139.6
June 12	1512	522.9	1509	66.6	1510	63.5	1511	≤0.3				
June 13	1524	555.5	1521	68.8	1522	67.6	1523	0.9				
June 16	-	-	1560	20.2	1561	38.4	1562	≤0.3				
June 17	1573	579.8	1570	60.0	1571	43.5	1572	≤0.3	1563	1318.8		
June 18	1583	479.8	1580	66.1	1581	73.1	1582	0.7				
June 19	1622	522.9	1619	60.4	1620	58.6	1621	6.4				
June 20	1629	563.7	1626	52.1	1627	52.5	1628	24.0				
June 23	1641	531.0	1637	19.8	1638	32.7	1639	2.7				
June 24	1669	580.0	1666	49.9	1667	46.4	1668	1.0	1640	1220.8		
June 25	1698	660.0	1695	61.9	1696	60.3	1697	6.9				
June 26	1719	500.0	1716	50.3	1717	47.0	1718	17.10				
June 27	1749	630.0	1746	64.1	1747	66.2	1748	22.9				
June 30	1765	640.0	1761	24.6	1762	28.2	1763	2.5				
July 02	-	-	1770	62.7	1771	67.7	1772	5.1	1764	1195.0		
July 03	1817	617.0										
July 04	1831	756.0	1828	54.0	1829	64.0	1830	22.4				
July 07	1837	756.0										
July 08	1872	638.0										
July 09	1893	650.0	1889	59.6	1890	68.5	1891	7.05	1892	1215.0		
July 10	1908	627.0										
July 11	1917	610.0	1914	56.9	1915	62.7	1916	11.60				
July 14	1933	547.0										

- Lagoon 2.6 Acres x 18 Feet Deep
- Average Liquid level 14 Feet
- Flow 2.2 ML/D
- Lagoon Influent/Average = 960 mg/L

Practical Aspects

The equipment used in aeration must satisfy most of the following mechanical and performance requirements:

- adequate oxygen transfer rates;
- proper mixing for liquid homogeneity;
- flexibility in the adjustment of both oxygen transfer and mixing;
- performance under adverse climatic conditions, i.e., low temperature and/or high winds;
- simplicity and reliability of design;
- ease of maintenance;
- low operating and maintenance costs; and,
- mechanical versatility.

In practice, each application has its own particular set of requirements or priorities. The emphasis in mining, for instance, is in good mixing to suspend the solids even though an adequate supply of oxygen is necessary for the biological process. On the other hand, sewage treatment operators place more emphasis on oxygen transfer for adequate BOD removal. Reliability is more of a factor for remote locations whereas ease of maintenance may be prized more by urban operators. In addition, external factors such as odour control and the introduction of cold air into treatment systems also make demands upon the flexibility of design of various aeration systems. The versatility of centrifugally pumped air induction systems may be the answer for an unprecedented number of specific application conditions which can be met in a very simple way with little alteration to existing designs.

The addressing of each separate requirement should demonstrate the capabilities of centrifugally pumped air induction systems. Oxygen transfer rates, as stated earlier, are competitive with alternate aeration systems. In mixing the surface "AREAS of influence" observed are obviously those of similar mixing impellers. However, as opposed to many other aeration systems, the present system creates a large "VOLUME of influence" by the air transfer/mixing combination at depth. Process flexibility is provided simply by speed control. Using several sheave arrangements the impeller rotation can be varied to provide varying degrees of mixing and oxygen transfer. Performance under varying conditions and reliability are both functions of ruggedness of construction and simplicity of design. These systems contain no subsurface joints or bearings; the shaft and impeller form one single subsurface rotating unit. This elimination of the need for subsurface moving parts, reduces the adverse effects on machinery for which liquids are notorious. The ease of maintenance of the centrifugally pumped air induction systems is provided by simplicity in design. Again the advantage of combining oxygen transfer and mixing into one process has allowed for a minimum of mechanical parts minimizing the need for maintenance. This fact was demonstrated in the Edmonton plant where aside from maintenance due to the two problems identified above which have been addressed little maintenance was required. Finally low operating and maintenance costs are functions of oxygen transfer efficiencies and low maintenance requirements both of which have been previously discussed.

Summary and Conclusions

A high speed turbine impeller capable of inducing air without the need for a compressor proved very successful in aerating wastewaters. Good oxygen transfer rates and appropriate mixing were achieved simultaneously at different speeds. Problems related to plugging and salt deposition were addressed and resolved proving versatility, simplicity of design, ruggedness and mechanical reliability.

To date every field problem has been addressed resulting in the production of an induced air unit that provides a good degree of versatility by:

- transferring increasing amounts of oxygen with increasing speeds;

- emphasizing either mixing or oxygen transfer simply by changing impeller speed or configuration;

- screening, when required, the intake by adding an easy to install dynamic screen;
- coating the impeller with urethane to prevent salt precipitation and minimize corrosion; and,

- producing different flow pattern with different impeller configurations.

WATER TREATMENT PLANTS AND COMPUTERS

Karl Welz
Water Treatment Plant Operator
E. L. Smith Water Treatment Plant
Edmonton

Computers are assuming a much greater role in the day to day operations of modern water treatment facilities. At the E. L. Smith Plant, applications have been developed which encompass a large array of tasks traditionally performed manually. Operations utilize DEC PDP-11/44 minicomputers in monitoring and process control of plant systems. Applications are continually being developed with the objective of achieving total automation. A second minicomputer runs the SCADA (Supervisor Control Data Acquisition) software which handles the distribution network throughout the City and surrounding areas. Administration has incorporated an IBM-PC to assist in budgeting, report generation, and data analysis. Preventive and scheduled maintenance functions are also enhanced by use of the microcomputer. This paper provides an overview of the above computer applications currently employed at the E. L. Smith Water Treatment Plant.

The topic I would like to discuss is computer applications in the water treatment field.

Edmonton has two main water treatment plants at Rossdale and E. L Smith. There are three plants at Rossdale, and E. L. Smith is sometimes called Number Four Plant.

Computers have been in use at these facilities for quite some time and development of computer control systems takes place on an ongoing basis. Rossdale presently is undergoing refurbishment and does not as yet posses a process control system. It does, however, house the distribution control system for Edmonton and area. E. L. Smith does have a process control system but the computer is not being fully utilized as of yet. Coordination takes place between the two plants to control the water distribution flows and pressures as well as reservoir filling and emptying.

In general, it seems that more and more use is being made of computers. Like most things though, computer use has its advantages and disadvantages.

Advantages

1. Speed and Accuracy

Computers operate at very high rates of speed and so can process a great deal of information in a relatively short period of time. If the programming and input of data is correct, then the end result will also be correct. The potential for errors is reduced when a computer is used for solving some tasks. Computers are particularly adept at manipulating numbers. Thus, for example, if a person enters a long list of numbers on a hand calculator and then finds the average value: it is possible that this tedious task could lead to a false result due to incorrect entry of a number or not using the right procedure for finding an average. If the computer has the correct programming and inputs, it can collect these numbers and find their average in a fraction of the time a person takes to do it manually with far less probability of error. Long, repetitive, tedious and often complex tasks can be done by a computer more efficiently than manually by a person. Where judgement, thinking, and creativity are required, however, the human has it hands down over the machine.

2. Continuous Monitoring and Process Adjustment

There are many process variables that need to be monitored through several process stages. (These include: flow rates, temperatures, pressures, pH, total hardness, total oxidants, alkalinity, UV and GC analyses, fluoride, chlorine, chlorine dioxide residual concentrations, colours, calcium hardness, etc.). The computer does not become tired, have off-days, or times when its "attitude" may not be the best, all of which can occur with people. The entire time a computer system is functioning, it is continually scanning for alarm conditions, for example, or maintaining a certain chemical flowrate as minute fluctuations are taking place. To manually do a chemical feed test, a pH test for example, requires a person to go out and physically take a grab sample: the pH test on which would only be relevant for the instant in which the sample was collected. With an on-stream pH probe hooked onto a computer system though, the pH of the water flowing past the probe would be taken continuously. Manual testing so frequently is not possible. During periods of rapid water condition changes, frequent manual testing may not be possible because of more immediate tasks that require attention such as draining or dosage adjustments. If done, the grab sample may be taken during a time when a change has not yet occurred, that is to say, the change has not yet reached the grab sample point and so would not register. The next manual grab sample may be done at a time when the change has already taken place (the change has already passed by and so it is too late). If conditions are still not normal, this second grab test would show the abnormality but not for how long things have been out of whack. The type of fluctuations which took place between the two grab test samplings and their degree would also be unknown. Corrective action could not be taken at the earliest possible moment, that is, when things just begin to go wrong. This is not the case with a correctly operating computer monitoring system. Similarly, an operator's time is not efficiently spent say by standing at a pump and continuously adjusting its speed by hand to maintain a steady output pressure. A computer could monitor the pressure and via controllers make many, small corrective adjustments continuously over 24 hours to keep the pressure steady at a particular set point value.

3. Remote Control and Data Gathering

Often a process is located far away from an operator: a low lift pumphouse or field reservoir, for example. Also the instruments and gauges at these areas would also be far away. To manually operate the equipment or collect numbers from these gauges and instruments would necessitate the operator physically travelling to the remote places. This could be time consuming and not efficient of his/her time. Remote control via computer for start/stop, open/close, on/off, and set point adjustment is much more convenient. Suppose that the numbers from places in these remote locations were used to generate a daily report. By using the computer, exactly at midnight all these numbers could be gathered and operated on to generate the required information in a short period of time. The status of pieces of equipment can be quickly ascertained and displayed on a screen. Alarms, reports or other information can be logged at the necessary times on magnetic storage media or on paper.

Disadvantages

1. Expense and Maintenance

Computer systems hardware, control instruments, and software programs are often very expensive and may not justify their cost. The water treatment operation would be more efficient when computer controlled but the operating budget may not allow its purchase. If the manual operation is acceptable and not in need of improvement then operations may be able to get by without. Even in the case of implementation of a computer control system or of individual microprocessor-containing controllers; it is still important to provide manual backup and for the operators to still remember how to run the plant in manual mode.

Much time is usually spent to initially install a computer system, set up instruments and wiring, and in programming. Time must also be spent in training the operators in the use of the system. Debugging the system until smooth operation takes place also takes time. Finally there is a need for regular maintenance of the system such as periodic tuning and calibration of the instruments. As you can see, the computer system is not usable right away and it may take some time before everything is working to satisfaction.

2. Sensitivity and Reliability

Computers are sensitive to power fluctuations or failures which can erase memory or cause data to be corrupted. A daily report would not be accurate, for example, if the computer system were down for a few hours. Static electricity or magnetic fields generated by such items as motors, telephones, appliances and so on, also affect computer systems. They can lead to fried chips and cause erasure of magnetic storage media. If the heads crash into a disk drive and damage occurs, the computer system may be out of operation for some time. Thus the need for considerations such as dual computer systems, static free and air conditioned/climate controlled environments, power conditioners, and uninterruptable power supply systems. Frequent backup of valuable gathered information and computer system maintenance are also wise to carry out. There is also a need for scheduled maintenance and calibration of instruments as well as other equipment sending data to the computer. For example, a small thing such as a scale set to the wrong range or condensation occurring on say a turbidmeter glass, will result in false data being sent. In fact, due to the speed with which computers operate, a lot of garbage can be spewed out because of incorrect data inputs or faulty program or hardware. It cannot be taken for granted that a computer readout is necessarily correct or accurate; judgement and common sense still needs to be exercised on the part of the operator or people using and interpreting computer generated information.

Now I would like to give a description of the systems we have at Rossdale and E. L. Smith Water Treatment facilities.

THE ROSSDALE COMPUTER SYSTEM

From the work station, requests can be made for station graphic, alarm and command list displays, system data summary, alarm, disabled alarm, trend, station name and command queue displays, and CRT erase function. The top row of letters (Q through P) on the keyboard are used for these requests.

The displays available together with their corresponding keyboard entries are as follows:

Q - System Command Queue Display
W - System Station Names Display
E - Erase CRT Function
R - System Data Summary Display
T - Trend Display
Y - Disabled Alarms Display
U - System Alarms Summary
I - Station Command List Display
O - Station Alarms Summary
P - Station Graphics Display

To request a station display, the numeric value for the station number is entered, followed by the letter corresponding to the desired display function. (The station numbers are given in the Station Names Display.) Once a station has been selected, further station display requests will default to the last station number entered unless a new numeric value is entered. For example, the sequence 13P will produce the station graphic display for station 13. If the letter I is pressed next, the station command list display for station 13 will be displayed. However, if 8I were pressed, the station command list display for station 8 would be displayed.

The DATA ACQUISITION and CONTROL SYSTEM is designed to provide operating information and control capability for the Edmonton Water Distribution System. The system currently monitors the discharge at the two treatment plants (Rossdale and E. L. Smith), 10 reservoir sites, a booster station at Millwoods and Burnewood, the water delivery to a group of suburban customers, plus pressure at a number of designated points around the City.

Reservoir Sites

1. Rosslyn
2. Papachase
3. Londonderry
4. Thorncliffe
5. Millwoods
6. North Jasper Place
7. Ormsby
8. Clairview
9. Castledowns
10. Kaskitayo

Suburban Customers

1. Morinville
2. Namao
3. St. Albert
4. Parkland
5. Strathcona
6. University of Alberta
7. North East Water Board

Data is gathered from transducers located at the various measuring sites and stored in a remote terminal unit (RTU). The central computer communicates with the RTUs to gather the data and store it internally. From the internal storage (called a data base), the data is available for display and reports.

For operator convenience, the data is displayed in groups divided according to stations. There are 15 stations currently designated.

1. Rossdale
2. Edmonton City
3. Suburban Customers
4. Rosslyn
5. Papachase
6. Londonderry
7. Thorncliffe
8. E. L. Smith
9. Millwoods Booster
10. Millwoods Reservoir
11. North Jasper Place
12. Ormsby
13. Clairview
14. Castledowns
15. Kaskitayo

Communications between the RTUs and the central computers takes place over leased telephone circuits. There are two telephone circuits in this system. One connects the 10 reservoir sites and the Millwoods Booster station. The other gathers data from E. L. Smith, Rossdale, the suburban customers, and the various pressure points given under the Edmonton City station. The RTUs are connected in a party-line style, i.e., any information sent from the computer facility to any one RTU is received by all RTUs on the line. It is the responsibility of the RTU to decode the data sent from the computer and respond only when it has been addressed.

The data returned from the RTUs contains a security check (BCH) which is used to determine if errors have been introduced into the data during the transmission process. Should an RTU fail to respond to three consecutive polls by the computer, or if the returned data contains an error in the security check, the data is discarded and the data point is marked as invalid in the data base. Should the response occur on the first address of the RTU, a communication failure alarm is generated. The data returned to the central computer by the RTUs falls into three categories: analog, status, and alarm. Status information provides the computer with an indication of the state of a device or operation at the remote station. For example, the state of a pump (running or stopped) or a valve (open, closed, or travelling) returns to the computer as status information. If a status point changes state without being commanded to do so, the state change will generate an alarm at the control centre.

Alarm information is similar to status information in that it provides the computer with an indication of the state of a device or operation at a station. However, the response to this data by the computer involves making the operator aware of any change in this state. This is done by displaying the alarm message on the CRT, logging the change on the printer, and sounding the alarm bell. The alarm is stored in the alarm queue (which is displayed in the alarm summary) and remains there until it returns to its normal state.

Analog data consists of process variables such as pressures, flow rates, levels, etc. These variables are read by transducers at the stations and coded into digital information at the RTUs. This digital information is read by the computer and translated into a numeric value before it is made available for displays and reports.

The computer can also send data back to the RTU. There are two types of data returned. The first type (called a digital output) causes a relay to open or close at the RTU which in turn causes some field action to occur (pump start, valve close, etc.). The second type of data contains analog information. This information (called a setpoint) is used at the station as a control variable input to some type of controller.

The central control facility contains two computers, a number of input and output devices, and a switch to move the devices from one computer to the other. One of the computers acts as the master and the other as the slave. The master computer communicates directly with the RTUs and has the responsibility of informing the slave of the status of the field devices. The master can run without the slave. However, if the slave is running and the master becomes inoperable, the slave activates the switch to move all the input and output devices to itself and it then takes over as master.

The computers at the central control facility are DIGITAL EQUIPMENT CORPORATION (DEC) PDP11/44s, each with cartridge disk drives and a communication link between them. The input/output devices consist of an event logger (DEC PRINTER LA120) in the control room, three CRTs, two functional keyboards, and a trend/report printer in the computer room. One of the CRTs is a high resolution monitor while the other two are low resolution.

The computer at the central control facility performs five major functions - scanning, alarming, displaying, supervisory control, and storing analog values for future reference.

The computer will continuously scan the RTUs for input data on a priority basis. The RTU point with the largest time since last scan/desired time between scans ratio, has highest priority. The input data consists of status indications, alarm indications or analog values. The action taken by the computer is dependent on the type and value of the data returned. If an RTU fails to respond to a poll by the computer, or if the returned data has errors in the security check, it will be polled again. If good data is not received after three consecutive polls, this data point is flagged as having questionable data and the scan continues to the next point. If this was the first point in the RTU, an RTU communications fail alarm is generated.

The RTUs are on two communications lines. The first line (loop 1) contains RTUs for the Rossdale station, the E. L. Smith station, and the City and suburban customer stations. The second line (loop 2) contains all 10 reservoir RTUs and the Millwoods Booster RTU. Based on this configuration, the average point update times (in seconds) are:

Alarm/Status	30
Pressures	30
Flow Rates	60
All Other Points (levels, temperature, etc.)	120

Analog variables are converted to electrical signals and then coded as digital information at the station. When this information is received by the computer, it is decoded to obtain the corresponding field value. This converted value is checked against a range for the type of signal transmitter from which it was generated at the station. If this value is within the signal range, it is stored away. If the value is outside the range for the type of signal, it is assumed that hardware problems have occurred and the value is treated as unreliable in the same way as a communication failure for the point and is not stored. In such a case the value for this point currently stored in the data base is flagged as out-of-data. Valid analog values (i.e., those within the signal range) are also checked against an upper and lower alarm limit. If the value is outside these limits, but was not outside these limits on the previous scan, an alarm is generated. A return to normal alarm is generated when the value comes back within the limits.

Alarm information provides the state (alarm or normal) of an alarm point at a station. Incoming alarm data is checked against the previous value of the alarm point. If a change has occurred, an alarm is generated for that point.

Status information provides an indication of the state of devices or operations at the station. When status information is retrieved, it is divided into two categories: logging and non-logging. Logging status points produce a one-line log on the event printer. Non-logging status points are simply retrieved and stored away for display or reporting purposes. Status points which reflect the state of a device which can be remotely controlled are set up as alarm points at system start up. This causes the system to generate an alarm if one of these devices changes state without being commanded to do so. When a command is issued, the corresponding status points are disabled from alarming for a specified time period. If the status changes during this time, the change will be treated as a status change and not an alarm.

There are four sources of alarms on the computer system:

1. Alarm indications returned from the field in response to a scan
2. Communications failure
3. Analog values outside their alarm limits
4. Restarts on the computer

The computer responds to an alarm condition by flashing the alarm at the bottom of all CRTs, logging the alarm on the printer, and ringing the bell on the printer. The bell will continue to ring until the operator acknowledges the alarm. An incoming alarm is placed in an alarm queue in the computer. This queue contains all current alarms in the system in the order in which they occurred and can be displayed by the SYSTEM ALARM SUMMARY function. Alarms remain in the queue until they have been acknowledged and have returned to normal. The queue has provision for 120 entries. When the queue is full, an "ALARM QUEUE FULL" message is printed on the printer and the bell sounds. This will be repeated until the operator executes the acknowledge function. Any alarm received during the interval between filling the alarm queue and acknowledgment cannot be entered into the queue and may therefore be "lost".

System restart alarms occur whenever the computer is restarted for any reason. System restart alarms always return to normal when they are acknowledged.

Alarms may be disabled by the operator through the functional keyboard. The alarm, when disabled, is ignored, i.e., any conditions causing an alarm for this alarm point are not reported to the operator; will not be entered into the alarm queue and therefore will not cause the alarm bell to ring. For example, a faulty transducer with an equipment malfunction can cause a series of nuisance alarms. It can be disabled until the source of the problem is rectified and then it can be reenabled. Disabled alarm points are treated as non-logging status points until they are enabled.

One-line log messages will be produced by status or alarm changes or by certain operator actions. The format of the messages logged on the printer is as follows:

```
DATE         TIME        MESSAGE TYPE        MESSAGE        ACTION
```

For example, the message for a pump status change could appear as:

```
10-Dec-82    10:03:08    ST  ROSSLYN PUMP        2          ON
```

The message type field is five character positions wide. The message type is a two-character code which specifies the origin of the message. If the message results from changes at an RTU, the code appears in the last two character positions of the message type field. If the message results from action taken at the control centre, the code appears in the first two character positions. The code types are:

ST - status message
AL - alarm message
CM - command or setpoint transmission log
EN - alarm enable message
DB - alarm disable message
DE - data entry message
LM - limit change message

The alarm message code is preceded by "**" when the alarm goes into the alarm state. The message description gives an English mnemonic description of the point being referenced. For example, ORMSBY STATION TEMP describes the temperature alarm at the Ormsby station. The action description describes the operation or state of this point, for example NORM, FAIL, ON, OFF, etc.

A number of reports are available from the computer system. Some of these reports are generated automatically while others are available on demand through operator requests. All automatic reporting will be done in the computer room while the reports requested manually by the operator will be generated in the control room on the event logging printer.

Automatically Generated Reports

Trend Reports

The computer system has the capability of storing historical data for up to 84 different analog points for the use of operations personnel. Four of these points are reserved for use by the operators, the remaining 80 are reserved for producing the automatic trend reports. When an analog is being trended, its value is saved at four-minute intervals. These values are recalled on the trend report which graphs the analog values against a time axis. The trend reports consist of from one to four trend plots. Each plot contains the graph of one analog's history together with the current alarm limits for that analog. At midnight each night, trend reports for all the analogs trended over the previous day are produced. In addition, the trend values stored for that day are collected and daily average is calculated. This daily average is then stored. The daily average trend values are also recalled on a trend report at midnight on the last day of the month. At midnight on the last day of the year, trend reports of monthly averages are generated. These monthly averages are calculated from the daily averages being stored but are not themselves stored. The analog points being trended can be changed at any time by system maintenance personnel.

Reservoir Storage Reports

At 7:00 a.m. each day, a report of reservoir storage levels for 7:00 a.m. and the previous midnight is generated. At month end, a graph is generated for each reservoir site. Each graph contains two curves, one reporting the midnight storage levels for each day of the month, the other reporting the 7 a.m. storage levels.

Pump Run Time Reports

This report is generated monthly and shows the accumulated run times for each of the pumps for which status is available. The total run time for all of the pumps at each station is also given. The run times are zeroed at the end of each month once the report has been generated.

Metering Reports

At midnight each day a metering report is generated giving meter through-puts for the previous 24 hours. The value for water pumped is derived by taking the meter value at midnight, minus the value at the previous midnight and multiplying it by the meter factor. The total of the through-puts of the eight meters plus No. 4 Plant is given as well as the total for the three power plants and the sum of the plant use and Water Treatment Plant No. 3. The total water pumped is then derived by subtracting the power plant through-put and the water plant through-put from the total through-put. A year-to-date through-put figure for the power plants, the water treatment plants and the total water pumped is also given. At midnight of the last day of the month, a monthly metering report is produced. This report is identical in format to the daily metering report, however, the previous meter values are the values saved at the end of the previous month.

Daily Summary Reports

At four minute intervals the computer system checks the discharge flow readings at the treatment, the reservoir sites, and the suburban customer sites to find the maximum flow for the day. At the same time it checks the flow over the last hour to find the maximum through-put at each of these sites over an hour time span. At midnight a daily summary report is generated to report the peak flow for the day, the maximum hourly through-put, the through-put for the day, and the average through-put for the previous five days for all the above mentioned sites. In addition it provides the maximum hourly through-put for the year and the day on which it occurred. The computer also calculates an instantaneous demand value. This is derived by summing the flows out of the treatment plants and the flows out of the reservoirs and subtracting from this the flows into the reservoirs. This value provides an instantaneous value of the water being consumed. The demand value is given in units of ML/D. Since some of the flows required for this calculation are not being measured through the telemetry system, they must be entered manually. This includes flow at Rosslyn, Papachase, Londonderry, and Millwoods. The demand value is checked on a four minute interval in the same manner as the other flows mentioned above to detect a maximum hourly value and a daily average value. In addition, the system keeps a daily average for the demand for the year-to-date and also keeps a maximum five day average for the year-to-date. These values are reported on the daily summary report.

Three reports are available to the operator on demand.

System Alarm Summary Report

This report gives the contents of the alarm queue which is a list of all alarms currently active in the system. Alarms are listed in chronological order from the most recent to the oldest. The time of the alarm, a description (i.e., the alarm name) and message (the alarm state) are printed for each alarm.

Pump Run Time Report

The pump run time report is also available on request. The automatic version of this report was described earlier. The format of the demand version is the same as the automatic, however, the values given for the demand report are the current pump run times for the month, i.e., the total accumulated run time from the beginning of the month to the demand report request time.

Data Summary Report

The data summary provides current system data for:

inlet pressure (kPa)
discharge pressure (kPa)
temperature (° C)
discharge flow (L/s)
level (M)
current reservoir volume (mL)
reservoir percent full
intake flow (L/s)

Current values for these variables are given for each of the ten reservoir sites. The system demand is also given (in mL/D).

The CRT provides an interactive display of system parameters for operator information. The top line of each display is reserved for the title as well as time and date. The next 43 lines are used to produce requested displays. The bottom of the CRT screen is used to display the last unacknowledged alarm received (displayed in flashing red) and an operator interaction area. Displays are divided into two types: station and system oriented displays.

Station Oriented Displays

Station Graphics

The graphic display of a station contains a schematic layout of the station with the current values of the analogs and current status of field devices. On the left (beneath the analog values), any alarms which are active at that station are displayed in red. The dynamic portion of the display (time, alarms, analogs, and statuses) are updated continuously as long as the display remains on the CRT. The analog data is displayed in green on a black background if it is valid and within limits. If the value exceeds specified limits, the value will be displayed in red. If loss of communications or false analog signals result in unavailable readings, the last available reading is displayed in reverse video (black on a green background). Symbols which reflect status at the RTU use the following colour code:

RED - open or on
GREEN - closed or off
YELLOW - transit condition

A summary of the symbols and colours used can be obtained by requesting the graphic display for station "0". All inlet piping is magneta (purple) and outlet piping is cyan (light blue). Any device which does not have status read back from the station RTU is displayed in cyan. The graphic display can be requested on any of the CRTs.

Station Alarm Summary

This display lists all points in the alarm state at the selected station up to a maximum of 38. If more than 38 alarms are present, only the last 38 are displayed. Unacknowledged alarms are displayed in yellow, acknowledged alarms are displayed in green. This display updates every few seconds. Just like station graphic displays, this display is available on any CRT. It should be noted that alarms cannot be acknowledged from this display.

Station Analog Limits

The limits display lists all the analog points at the selected station which have operator assignable limit ranges. Each of these points is accompanied by the analog range and the current limits. The operator may change any of these limits.

Station Command List

The command list display provides the operator with a list of all the equipment commands which can be issued at the given station from the computer centre. The list consists of two parts: Digital outputs and setpoints. For each command a two-digit number is given followed by a description of the command. The number is used to identify the selected command point when the operator executes a control command at the station. The first digit of this number is used to designate the device type and the second digit specifies the unit number. The command list display can be requested on any CRT. Commands can only be issued if the command list or the graphic display for the desired station is present on the CRT directly in front of the keyboard requesting the command.

Data Entry Display

This function is used to manually enter any data points which are not read through the telemetry, but may be required for displays, reports or calculations. Points are listed with an English description and their current values. From this display, the operator can change the numeric values for any of the points listed. The data entry function for station number 0 is used to enter the meter readings for the high lift pumps for the daily and monthly metering reports.

Trend Assignment Display

The operator can request trending for up to four variables at any one time. This display shows the names and analog numbers of the variables currently being trended. If the operator requests a change, a list of all the available analogs at the requested station, along with their analog identification numbers, are listed on the lower portion of the CRT screen. The operator may choose not to change any of the assignments, in which case, the names and analog identification numbers of the variables currently being trended will remain on the screen.

System Orientated Displays

System Alarm Summary

This display lists in chronological order, all outstanding alarms in the system up to a maximum of 38. If more than 38 alarms are outstanding, only the latest 38 will be displayed. The display does not update on its own. It is redrawn when reselected, when alarms are acknowledged or when an alarm is disabled.

Data Summary

The data summary display gives a system overview of analog data. It provides the operator with a summary of the entire water distribution system. The values are updated to remain current as long as the display remains on the CRT. The colour coding for the values is the same as the analog data on the station graphic display. Inlet pressure (kPa), Discharge Pressure (kPa), Temperature (°C), Discharge Flow (L/s), Level (m), Current Volume (ML), Reservoir Storage (% full) and Intake Flow (L/s) are shown for each of the reservoir sites and also for the booster stations. This display also contains a value for system demand. This value is derived by adding the flow outputs from the two treatment facilities and the reservoirs and subtracting the flows into the reservoirs. The result gives the flow from the system to the water users (in ML/D).

Disabled Alarm Summary

This summary display gives a list of all alarm points currently disabled. The list shows the disabled alarms from oldest to newest. If more than 38 alarms are currently disabled, the latest 38 disabled alarms are shown.

Command Summary

This display provides a list of the latest commands issued by the operator along with the time each command was executed and an indication whether the command transmission failed or succeeded. (This does not indicate whether the command successfully completed, only whether the command was transmitted successfully.) The display is limited to the last 38 commands issued and does not refresh unless re-selected.

Trend Display

The trend display gives four separate plots of analog values sampled every four minutes over the past 24 hours. The analogs being trended are selected by the trend assign station function. Two red lines appear on each plot. These represent the high and low alarm limits chosen by the station limits function. This display remains active as long as it remains on the CRT. Every four minutes the current values of the analogs are added to the end of the display until a new hour occurs at which time the entire display is redrawn with a new time axis. The display then continues to update every four minutes or until a new display is chosen. The axis appears in white, the axis labels are yellow, subheadings and time are displayed in magenta and the headings are cyan. The actual plot is green. This display can be requested on any of the CRTs. However, if it is displayed on a low resolution CRT, the colours of the axis and the plots may overlap and the plot lines are much thicker. Choosing the display on the high resolution CRT produces a much clearer result.

Station Names

The station names display is a static display giving the operator a list of the station names as well as the station numbers used for requesting station orientated displays. In addition to this, the storage capacity at each station is listed. The data is displayed in green on a black background.

The computer provides the operator with the ability to issue commands to the RTUs at the remote stations. Such commands as pump start or stop or valve open or close, are supplied. A list of all available commands at a given station is available through the station command list function display. There is no automatic control from this system, all control outputs are initiated by the operator.

Historical Data Storage

This system contains a historical data storage function which provides the data storage for the trend display and trend reports and also for the flow values on the daily summary report. A maximum of four analog variables can be assigned for trending by an operator and recalled via the trend display. A maximum of 80 additional analog variables can be assigned for trending by a computer system manager. These 80 will be displayed on the printer automatic trend reports.

The values of the analog variables assigned for trending are stored in the computer disk storage every four minutes. These values are retained for up to two months before they are overwritten. In addtion, the daily average value of the 80 variables assigned by the system manager are retained for up to two years. These values are reproduced on the daily average and monthly average reports.

The analog values are stored in groups (called records) of one hour duration. For this reason, changing a trend assignment from one variable to another destroys the data for the original assignment for the hour currently being stored, but any data stored prior to this hour for that variable, will be retained for the two months it takes until this data is overwritten.

Two computers (CPUs) are available to monitor and control the water distribution system (Rossdale presently does not have computer plant control). This is known as a dual CPU configuration. For reliability, one CPU is "online" and the other is in "standby" mode. The online CPU is referred to as the "master". All communication lines and peripheral equipment (CRT displays, function keyboards and printers) are connected to the master CPU. It performs all data scanning and processing functions, and maintains an updated database. The standby CPU is referred to as the slave". It receives periodic (once per minute) database updates from the master CPU via an inter-processor communication link and remains ready to assume online status if required.

If a CPU is taken out of service for maintenance or other "offline" purposes, it is returned to service by "bootstrapping". This is a hardware/software procedure for reloading the CPU memory form disk memory with the operating system software. In order to maintain one version of software, which is interchangeable between CPUs, the bootstrap procedure requires interactive dialogue with the computer operator. This dialogue takes the form of computer prompt messages and operator responses determine how the CPU is returned to service. For example, it may return as a master or as a slave. Also, it may return with an updated database received from the other CPU, or it may return with its own database regardless of when it was last updated.

The slave CPU assumes master status by an interaction of software and hardware. The CPU designated "master" by the bootstrap procedure described above, assumes it has control of communication and peripheral lines. The CPU designated "slave" by the bootstrap procedure will normally run as slave until the periodic database updates from the master are interrupted.

When these updates stop, the slave will attempt to switch the communication and peripheral lines to itself and automaticaly change its operating software configuration from slave to master.

The hardware design imposes a restriction on the dual CPU configuration's ability to automatically switch CPU masters. One CPU is permanently designated as "primary" and the other as "backup". The backup CPU may automatically become master if the primary CPU fails, i.e., stops transmitting database updates. However, the primary CPU cannot become master automatically if the backup CPU fails. In this way the "master" role may automatically switch from primary to backup CPU but manual intervention is required to switch back again.

In this system, the primary CPU is labelled "A" and the backup CPU is labelled "B". A switch labelled "MST", located on the lower right corner of the back of the switching cabinet, controls whether communication and peripheral lines are switched automatically or manually. If the MST switch is down, switching is automatic; if it is up, switching is manual. The switched position of the communication and peripheral lines is indicated on the "System A" and "System B" lights located on the front of the switching cabinet.

THE E.L. SMITH COMPUTER SYSTEM

The E.L. Smith computer system is virtually identical to that of the Rossdale Plant. Differences between the two systems include:

1. Rossdale has an earlier version of the software.
2. Rossdale has presently no in-plant computer control or monitoring of equipment.
3. E.L. Smith monitors but does not control field reservoirs, though the capability exists.

The E. L. Smith Water Treatment Plant can be operated in totally manual mode, fully automatically via computer control, or in some combination of the two, which is the usual mode of operation. Also, in certain cases, the capability exists to operate in a semi-automatic mode via locally installed controllers. Examples of pieces of equipment which include their own microprocessors are: the high and low lift pumps, filters, a few of the chemical feeds such as one of the lime feed systems, and the liquid alum feed system.

Each major area of the plant has its own control room containing a computer control console consisting of a keyboard and CRT screen. Only the area in which the control room is located can be computer controlled but the entire plant can be monitored from any of the control rooms. The exception to this is the master console located in the main control room, which has access to the entire plant. In addition to a computer console, each control room has a mimic panel depicting schematically the area served by the particular control room. The main control room's mimic panel is of the whole plant. Other pieces of the plant computer are also located in or near the main control room: two CRT/keyboard control consoles in addition to the master console, two DEC LA120 printers, one console similar to those at Rossdale, a system managers console and next to the main control room: the computer room proper housing an air conditioning system, system printer, and the two ("System A" and "System B") computers.

The E.L. Smith control rooms are:

1. the main control room
2. the chemical feed systems control room
3. the clarifier area control room
4. the filter area control room

A seventh console is located in the supervisor's office. The eighth Rossdale-style console is not actually part of the E.L. Smith system but communicates via modem over the telephone lines with Rossdale and is part of the Rossdale system. The ninth, system managers, console is used to gain entry to the software of the computer system for maintenance or additional programming. A tenth terminal located in the laboratory is identical to the system manager's console but it used to transmit laboratory data, entered by lab staff, from E.L. Smith to Rossdale over the phone lines.

Details concerning the operation of the system manager's console are beyond the scope of discussion of this paper, so I will not include them. The manner in which the Rossdale-style console functions was described in a previous section of this paper, and thus that leaves us with a description of the functions of the E.L. Smith system which follows.

HELP - It is appropriate to begin with this function key. Unfortunately not too much help is actually provided. When this key is pressed the computer has been set up to provide only a diagram on the CRT screen of the keyboard. This diagram shows the location and names of each of the keys but there are no associated displays describing the function of each of these keys.

MENU/HOME - This key will give a listing on the screen of the graphic displays available on the system. Each display will have a name by which it is accessed and will be in red or green. A red listing is protected and cannot be edited until it is changed to a green listing by gaining entry into the system via a password. The first question the computer asks is if the operator wishes to edit a display. If yes, the operator then answers the computer's question for the name of the green/unprotected display he wishes to edit. The operator then completes the changes to the display he wishes, protects it or leaves it unprotected, gives the display a new name if he wishes and then he is done. If the operator does not wish to edit a display, which is usually the case, he enters no and the computer will then ask which display he WOULD like to be displayed. The operator can then enter the name of the desired display or exit if he wishes to perform a different function.

GRAPHIC DISPLAY - This key will cause the computer to ask for the name of the graphic display the operator wishes to come up on the screen. If the operator is not sure of the name of the display he wants he can get a listing via MENU. Once into the graphic displays, the operator can move through the various displays with the arrow keys if he wishes. The PAGING display shows the arrangement of the graphic displays and how they can be moved through via the arrow keys.

RTU 1 are 10 series graphic displays = low lift pumphouse
RTU 2 are 20 series graphic displays = chemical feed equipment
RTU 3 are 30 series graphic displays = clarification area
RTU 4 are 40 series graphic displays = filtration area
RTU 5 are 50 series graphic displays = high lift pump area, onsite
storage, and electrical.

ESCAPE/EXIT - This key will erase an entry if the operator wishes to correct a mistyped entry, exit a function if the operator wishes to try again or go to a different function, or get rid of a computer question (prompt) if the operator does not wish to give response but rather go on to some other function. If there is an entry, pressing once will get rid of the entry, if the key is pressed once more then the prompt will disappear and escape from the function will occur.

DIGITAL STATE CHANGE - This key is used to turn OFF/ON, OPEN/CLOSE, or START/STOP a piece of equipment in the selected graphic display directly in front of the keyboard being used. Once this key is pressed, the cursor will position itself on the first digital output on the graphic display that the operator has selected and currently on the screen. At the top of the screen, the computer provides a description of the particular digital output point the cursor is currently positioned on. If the operator wishes to select a different digital output, he may move the cursor to the position desired by pressing the return key or the arrow keys. Once on the desired digital output the operator may press either the (START/OPEN/ON) key or the (STOP/CLOSE/OFF) key. The computer will ask for confirmation of the action. If the operator wishes to carry out the action he presses again the key he previously has already hit once. The computer acknowledges the confirmation, jumps to the next digital output, and prints out the action on the printer. The operator then presses exit if he is done or continues with more actions on that screen if he so wishes.
Note: Pieces of equipment will be RED if running or open, GREEN if off or closed, and BLUE if in a transition state.

ANALOG STATE CHANGE - This function key is usually used to change a flowrate or feedrate via a SETPOINT. First the desired graphic display screen is selected, once it is on the CRT directly in front of the keyboard in use, the ANALOG STATE CHANGE key is pressed; finally the operator selects the desired analog output point with the return or arrow keys. As the cursor positions itself on a point, a description of that particular point is displayed by the computer at the top of the screen. Once on the desired point the operator enters the required setpoint using the numerical keys and presses RETURN. The computer asks for confirmation and the operator responds by typing a Y for yes or a N for no. The change is acknowledged, printed on the printer, and the cursor goes to the next point whereupon the operator can exit or enter other setpoints.

DISPLAY PROCESS VARIABLE - This function key will display a measured field input to the computer (such as a flow, pressure, temperature, etc.). The computer prompts for the process variable and the operator responds by entering the desired process variable number or six character I.D. tag. These process variable numbers or I.D.s can be obtained from a graphic display which will have all variables on that screen labelled. The process variable display contains, in written out form: 8 attributes for the particular variable and a bottom line which shows if the variable is ON/OFF computer control, in ACTIVE/INACTIVE state, and shows the alarm state (MAXIMUM, MINIMUM, UPPER REFERENCE, LOWER REFERENCE, or NORMAL).

The 8 Process Variable Attributes shown are:

1.	CURRENT VALUE	This is the present measured value of the process variable.
2.	TARGET VALUE	If the variable is controlled, the current setpoint is shown.
3.	MAX. LIMIT	This indicates the hi/hi alarm.
4.	MIN. LIMIT	This indicates the lo/lo alarm.
5.	UPPER REF	This indicates the hi warning.
6.	LOWER REF	This indicates the lo warning.
7.	DELTA LIMIT	This indicates the amount that the variable may change/vary before causing an alarm.
8.	DEVIATION LIMIT	This indicates the degree to which the current and target values can differ/deviate before causing an alarm.

The three states shown at the bottom are:

ACTIVE/INACTIVE	Variable being scanned = ACTIVE Variable not scanned = INACTIVE
ON/OFF CONTROL	ON = setpoint can be sent. OFF = setpoint cannot be sent.
ALARM STATE	One of attributes 3-8 or NORMAL.

KEYS ASSOCIATED WITH THIS FUNCTION:

1. CHNGE TARGET VALUE A process variable setpoint change may be entered after this key is pressed. (NO CONFIRMATION!)

2. CHNGE CURRENT VALUE When a process variable is INACTIVE an operator may enter a change in its current value after this key is pressed.

3. CHNGE MAX VALUE After this key is pressed, the maximum alarm limit for the process variable may be changed.

4. CHNGE MIN VALUE After this key is pressed, the minimum alarm limit for the process variable may be changed.

5. CHNGE UPPER REF After this key is pressed, the upper reference alarm (hi warning) limit may be changed.

6. CHNGE LOWER REF After this key is pressed, the lower reference alarm (lo warning) limit may be changed.

7. CHNGE VARI DELTA After this key is pressed, the delta alarm limit for the process variable may be changed.

8. CHNGE VARI DEV After this key is pressed, the deviation alarm limit may be changed.

9. CHNGE ON/OFF STAT This key, unlike the above keys 1-8 (which are located on the extreme left of the keyboard) and like key 10 below, is located in the upper right of the keyboard. If the process variable has a controller this key will alter the controller's status from ON to OFF or from OFF to ON, i.e., opposite to that which is currently being displayed.

10. CHNGE ACT/INACT This key will take a process variable off computer scan or put it on scan. If ACTIVE status is currently being displayed, pressing this key will cause the process variable to be taken off computer scan (become INACTIVE). If INACTIVE is currently being displayed, pressing this key will cause the process variable to be put back onto computer scan (become ACTIVE).

    NOTE: If a process variable has a controller, the controller must first be taken off computer control via the CHNGE ON/OFF STAT key then the point can be taken off computer scan via the CHNGE ACT/INACT Key.

    NOTE: The display process variable key is labelled thusly:

FLIP (BAR GRAPH)
DSPLY PROC VARI

By holding down a shift key and then pressing the display process variable key, the upper portion of this key (FLIP [BAR GRAPH]) will be inacted. A bar graph representation of the process variable information will be displayed rather than the same information in written out form. Another way to obtain a process variable display in graphic form is via the SINGLE BAR GRAPH display key.

SINGLE BAR GRAPH - This function key will display a process variable in a bar graph format after the desired process variable number or I.D. has been entered in response to the computer prompt to this key. In addition to the 8 process variable attributes, displayed graphically on the bar graph itself, if the process variable also has a controller, then its controller attributes are also displayed in written out form next to the bar graph.

The 11 Controller attributes shown are:

1. TARGET - Shows current controller setpoint (target value)
2. TARGET MAX - Shows maximum enterable setpoint
3. TARGET MIN - shows minimum enterable setpoint
4. GAIN - shows gain of the controller
5. PROC GAIN - the gain factor between the process variable and controller
6. RESET MINS - reset of the controller
7. DERIV MINS - derivatives of the controller
8. OUTPUT MAX - maximum controller output possible
9. OUTPUT MIN - minumum controller output possible
10. MAX. ADJUST - the maximum amount that the controller output may change per scan of the computer
11. OUTPUT VAL - the current controller output

By pressing the CHNGE TUNING PARAM key, the operator can change any of the above 11 controller attributes.

CHNGE TUNING PARAM - This key allows the operator to change any of the 11 controller attributes of a process variable which has a controller. The single bar graph of the desired process variable must first be selected before this key can be used. Controller attributes of some process variables are protected and access can only be gained via password. The computer will ask for the item number (attribute number 1 - 11) the operator wishes to change. After the desired attribute is selected, the desired change can be made followed by RETURN. To change another controller attribute the CHNGE TUNING PARAM key must be pressed again and another attribute selected.

DISPLY DIG STAT - After the prompt which asks for a digital name, the operator enters a digital number, I.D.,, or simply RETURN. The display digital status key shows the status of a particular digital point and the following 15 points in the system. The next group of 16 digital points in the system can be displayed by pressing the RETURN key. Spare digital points are displayed as blanks.

ON/OFF CONTRL SUM - The on/off control summary will generate a display which will tell the operator which controllers in the system are presently OFF computer control.

The operator can select a particular RTU (RTU 1-5) or by pressing RETURN a review of all RTU's is displayed.

ACT/INACT SUM - The active/inactive summary key will generate a display which will tell the operator which process variables in the system are presently not being scanned. Again the operator can select a particular area by RTU number or by pressing RETURN a summary for the whole plant is shown on the screen.

ALARM SUM - This alarm summary key will display to the operator any process variables or digital inputs which are currently in alarm condition. Each RTU individually or the entire plant can be selected (via RETURN after the prompt) and the alarms paged through one at a time also with the RETURN key.

ALARM HSTRY DSPLY - This alarm history display key gives a chronological history of 200 analog and digital points that have gone into alarm, starting with the most recent alarms to the least recent alarms in. The display indicates when a particular point went into alarm condition, if it has returned to NORMAL, and the time it returned to normal. Page 1 contains the most recent alarms and page 10 the oldest alarms The operator can start with any page and step through the pages with the RETURN key. After page 10 the display begins again with page 1. RETURN pressed after the prompt will display the alarms beginning with page 1.

STOP ALARM HORN - The stop alarm horn key will stop the alarm horn from beeping at the console which received a system alarm. When a new alarm occurs the horn will beep again until it is again silenced by pressing this key. The alarm is not acknowledged with this key, however, and will still flash.

ACK ALARM - The acknowledge alarm key will stop the flashing of alarms on the screen. With the ALARM SUMMARY key a whole page of alarms (both digital input and process variable points in alarm) can be acknowledged. Each control room can only acknowledge alarms originating in the area served by that control room. The master console can acknowledge any alarm. To acknowledge a process variable alarm the screen (single bar graph or display proc veri) containing the point in alarm must first be called then the ACK ALARM key can be pressed. To acknowledge a digital input the digital point in alarm must first be called up on the screen by using the DISPLAY DIG STAT key, then ACK ALARM key can be pressed to stop the points in alarm from flashing.

DEF BAR GRAPH - The define group bar graphs key is used to specify the process variables an operator wishes to have displayed on a single screen. Each selected process variable will be displayed in single bar graph form. A group of one to eight process variables may be displayed on a single screen. The maximum number of groups is four (assuming each group contains the maximum number of eight process variable single bar graphs). To clear the assigned process variables from a group, type in G#=CLEAR after the computer prompt asking for group number and process variables assigned to that group. G# is the group number, e.g., G1 is group number 1. After this action the group in question is purged of all process variables and is blank. Process variables can now be assigned to this blank group in the following manner:
Assuming we wish to put process variables into G1

1. DEF BAR GRAPH allows entry into the function
2. G1 = CLEAR purges G1 of any previous variables
3. G1 = the desired process variable number or I.D.
4. Lastly the RETURN key is pressed.

One process variable has now been added to G1. If more process variables are to be added, the operator goes through procedure one to four for each additional process variable added to the group up to the maximum of eight process variables. At any point if the operator wishes to view the group bar graph he can press the GROUP BAR GRAPH key and enter the group he wishes to see. After the operator is satisfied with the way he has set up G1 he can continue defining more groups of process variables in G2, G3, G4, and so on, or purge any group and redefine the process variable points he would rather see in those groups. Groups which do not contain the maximum of eight process variables may have additional points added at any time up to the maximum. Once a group is full with the maximum of eight points, no new points may be added: the group must be purged first with G#=CLEAR.

GROUP BAR GRAPH - This key allows any group of process variables previously defined with the above function to be displayed. After the computer prompt asking for the group number, the operator enters G# (the group number he wishes to have displayed). A screen may display a group of from one to eight process variables in bar graph form. More than one group at a time cannot be on a single screen, i.e., one screen may not display both G1 and G2 at the same time.

DEF TREND PNTS - This function key lists groups and points, can be used to add or delete points to be trended or can make a scale change to a group of variables being trended (a group may contain only one variable).
Trending - A plot of process variable's measurement versus time.
Scale Change - The process variable trend display may be in two scales: the bottom and top of the vertical axis may be in the lowest and highest engineering unit attainable or in the lowest and highest measurement attained over time period trended.

There are three trend functions:

1. LST - When change is pressed followed by RETURN, 16 groups are listed. Each group may contain 0-4 process variables.

2. CHG - When change is pressed followed by RETURN, the 16 groups are displayed and in response to the computer prompt the operator may define, by process variable number or I.D., the group of points to be trended or purge any group similarly to the way a group bar graph is defined. More than one trend point can be defined at a time, however, unlike defining bar graph points.
   e.g., G4=CLEAR will purge G4 of all points.
   G4=23.45.55 will define G4 as containing process variables 23, 45, and 55. (Process variable tag I.D. name may be used instead of process variable number.)
   ESC key is pressed when all changes are done to exit this subfunction of DEF TREND PNTS.
3. SCL - Changes the scale in which all groups to be trended will be displayed. SCL then RETURN gives the prompt:
   ENTER 0 FOR DYNAMIC SCALE, 1 FOR INSTRUMENT SCALE >

   0 then RETURN - The next time a group is called up to be trended, the plot will have the bottom of the vertical axis = the lowest measurement attained over the time period trended for and the top of the vertical axis = the highest measurement attained over the time period trended for.

   1 then RETURN - The next time a group is called up to be trended, the plot will have the bottom of the vertical axis = the lowest engineering units possible and the top of the vertical axis = the highest engineering possible for the process variable. Over successive trends, then the vertical axis will always have the same fixed unit.

TRND DISPLAY - This trend display key will give a strip chart of a group of up to four process variables. The time period over which the trend is displayed on the screen is from the time the trend function is enacted to the end of 256 computer scans (approximately 20 minutes). A mark is plotted on the screen after each scan cycle of the computer, for each process variable in the group selected; after 256 scans the screen will contain a complete trend. At the end of 256 scans the screen refreshes, continuing trending with the first mark of the new screen being at the time of the last mark on the screen previous which has vanished. The computer will display a list of the 16 groups and the variables assigned to each group via the DEF TREND PNTS function and will prompt: ENTER TREND I.D.s >

1. An operator may enter one of the groups G1 - 16 or;
2. a group other than the 16 pre-defined may be defined. A particular process variable or up to four process variables may be asked for by process variable number or tag I.D. name. It is usually more convenient to set up the 16 groups with the process variables that most frequently need trending. Then this method of defining one to four different process variables will only need to be done for the ones that rarely need to be seen in a trended form. This method is most usually used as a quick check on a variable that infrequently needs to be analysed or monitored via a trend.
   Examples: ENTER TREND I.D.s > 2AL405 RETURN
   ENTER TREND I.D.s > 25.26.27 RETURN
   Note: A period is used between variables when entering more than one at the same time.

HISTOR DATA - The historian data key displays the trends of up to four process variables at a time plotted against an operator selected period of time. The time base for data gathered and stored in the historical disk is for 6 months. The method of accessing this data is fairly involved so I will not detail it in this paper.

REPORT - The report key is used to print out a hard copy of any of the library of report names in the system. Basically the operator just provides answers to prompts regarding type of report desired, the time it should cover, and the nature of the data the report should contain. The method of accessing this data is fairly involved so I will not detail it in this paper.

DYNAM DIG STAT CHNGE - The dynamic digital state change key is used to display the low lift and high lift control screen so that the operator can control the raw water flow in the low lift pumphouse and discharge pressure in the high lift pump area. Pressing the key once allows the operator to select 1 = low lift area, or 2 = high lift area. Pressing the key again after selecting either 1 or 2 allows data entry or some controlling action to be performed.

Low Lift Controlling Actions

1. raw water flow setpoint
2. follow and lag pump discharge valve setpoints (lead follows 1)
3 start/Stop of lead, follow, or lag pumps
4. change of pump sequence (the order in which the three low lift pumps will be assigned lead, follow, and lag status)
5. raw water flow deviation limit
6. stabilization time (the length of settling-in time the low lifts are allowed before checking for 5 takes place)
7. exit from data entry mode or cancel of an entry due to typing error or change of mind.

High Lift Control Actions

1. north and or South pressure setpoints
2. pump speed setpoints (for pumps on speed control rather than on pressure control)
3. start/Stop of high lift pumps
4. pump control mode selection (local or remote)
5. exit from data entry mode or cancel of an entry due to typing error or change of mind.

Microcomputers

Besides the minicomputer systems as Rossdale and E. L. Smith, we also utilize microcomputers to help with the day to day work at the treatment plants. We happen to use IBM and Sperry personal computers which are fairly standard micros. Each brand of computer has its own set of hardware/software often not compatible with any other brand or even with each other.

When people talk about computers they usually begin spouting a lot of obscure words such as RAM, ROM, DOS, BASIC CRT, VDT, FLOPPY DISK, and so on. This computer jargon can be confusing to people not familiar with the subject and can, in fact, become oppressive and a source of intimidation. The words tend to make concepts which are, in reality not too difficult to understand, sound complex. Unfortunately, the computer field, like most fields of knowledge, has developed its own set of vocabulary and this vocabulary must, to a certain extent, be learned for effective dialogue to take place. Fortunately, with time and as a person becomes more familiar with computers, these new terms are acquired and tend to become part of everyday communication. In these times, with computers being so prevalent, many people have had contact with these machines directly or indirectly.

A typical microcomputer usually consists of a display monitor, a printer, a keyboard, and the computer or system unit itself which usually has some sort of magnetic storage devices incorporated. Display screens fall into a few broad categories: monochrome or color: composite video, RGB, or TTL signal. Usually 80 columns by 25 lines are displayed at one time. The magnetic storage media can be a three-and-one-half, five-and-one-quarter, or eight inch floppy disk type or a Winchester/Hard/Fixed disk type of recording equipment. The floppy disk or hard disk can be read from or written to one or both surfaces and varies in the amount of information that can be stored on it according to its formatting. Different numbers of tracks and sectors can be laid on a floppy or hard disk giving different storage capacities. Internally the computer has a memory where information can be manipulated but when the power is turned off the contents of this memory is erased. Therefore there is a need for this magnetic media to store information in a more permanent fashion.

Some type of software/programs are needed for the computer even to operate. The operating system is the main program which enables a person to get some useful function out of a computer. It links all the various elements of the computer system such as the display, printer, keyboard and storage devices together. For example, the DOS (Disk Operating System) of IBM contains some 60 commands to perform various functions such as saving data to disk. The operating system software programs coordinate all the devices of the computer system allowing the user to: enter information into the computer, have the desired manipulations performed upon that information and then have the result output to a screen, disk, or on paper in the desired arrangement.

Common examples of information manipulation include text handling via word processing application programs, number handling via say a spreadsheet application program and the organization provided by a database application program. Application programs overlay and work in conjunction with the operating system programs. These three types of application programs, are most common: word processing, spreadsheet, and database. Others include Graphics and Telecommunication programs. Data from a database, for example, could be piped into a graphics program and the result may be, say, printed out on paper and incorporated into a word processing document in a disk file. This word processing document could then be sent to another computer over the phone lines using the telecommunications software after say a spreadsheet was included with the text and database records.

SOME EXAMPLES OF MICROCOMPUTER USE AT E. L. SMITH

Maintenance

The maintenance staff (which includes: electricians, millwrights, instrument technicians and utility workers) utilizes the PC everyday. Using the CIMP (Computerized Industrial Management Program) job completions, parts used, wages paid, time involved, etc., are entered every morning. Weekly maintenance checks are logged on the computer in a spreadsheet. The STORES department utilizes a parts and materials inventory and purchasing control system.

Clerical and Technical

Our secretaries use word processing, spreadsheet, graphics, and database programs for tasks such as general correspondence with: city council, between management and worker levels, school groups, equipment manufacturers and so on. Minutes of Union/Management meetings, Safety meetings, Charge Operator meetings and so forth are done on the computer.

Technical staff include:

A training officer who finds many uses for the computer such as training manual updates, examination preparation, student records, etc. A process control engineer, junior engineers under management as well as a systems analyst/computer programmer extensively use the computers for system development and maintenance. To this group belong the engineering technicians who prepare our monthly and annual reports as well as work on ongoing projects.

Managerial

Computers help our managers with coordination of all the workers and activities at the plants. The computer also plays a large role in budget preparations, chemical inventories and purchasing of all types. Project management and research is also enhanced by computer use.

Operations

The operations personel, of course are heavily involved with the computer systems. Quality control, chemical feed, filter operations, low lift/high lift and summary record sheets are kept. The minicomputers are used to help run the plant systems and distribution systems.

It is not usual that an operator will develop his or her own program. If the need for a computation or manipulation is not provided for by a commercial program (and it often is not in the case of the water treatment industry); then with a language such as BASIC a short, simple program to provide the desired result can be written. The MICROSOFT BASIC programming language, for example, contains about 200 keywords which, in combination. can make a program. Programming can be enjoyable and is not unlike learning a foreign language with which a problem solving methodology set of computer instructions can be developed for many purposes. There are many programming languages among which are FORTRAN, COBOL, ASSEMBLER, PASCAL and "C". Many hand calculators are now capable of being programmed and some even resemble a pocket computer or "lap-top" portable computer.

SUMMARY

A computer is just another tool in the work chest, all-be-it one slightly more sophisticated than a screwdriver, that people can use to help solve problems and attain a certain goal. In the case of our industry that goal is economically treating water to meet the best quality possible using the available equipment, knowledge, and skills of the water treatment plant and operations/maintenance staff respectively. Our product, potable water, must meet certain standards, be supplied in sufficient quantity, and be delivered at the proper pressures. A computer control system can go far in attaining this goal. Such a system can provide efficient monitoring and control of the many process variables involved and help in generating the records and reports necessary. In general, it can be said that the benefits derived from the use of a computer system in a water treatment facility outweigh the possible disadvantages.

MEMBRANE TECHNOLOGY
RELATED TO MUNICIPAL WATER TREATMENT
PRODUCTION OF POTABLE WATER

B. P. Herner, Vice President
Zenon Water Systems

In my presentation today, I would like to discuss the basic concepts of reverse osmosis, examine the physical phenomena of the reverse osmosis process and present data revealing the water quality obtainable, appropriate pretreatment, and basic costs of the use of reverse osmosis in water treatment.

Osmosis is a natural process whereby pure water separated from saline water by a semi-permeable membrane will exert a force to pass through the membrane to dilute the saline solution. This force is designated as OSMOTIC PRESSURE and is equal to approximately one psi for each 100 mg/L of total dissolved solids. The flow can be reversed simply by exerting a force on the saline solution which will cause ion free water to pass from the saline solution through the membrane, thus producing demineralized or deionized water.

It has been the task of the researchers to develop synthetic membranes that can perform this liquid/liquid separation reliably and economically.

The efficiency with which a membrane will produce pure water is measured by its ability to reject dissolved solids and the rate at which it can do so. The physical parameters that affect the rate of permeation of the membrane are the inherent permeability of the membrane to water, the pressure applied across the membrane and the thickness of the membrane. The ideal membrane therefore is one which is very permeable, very thin and can withstand high pressures. In addition, it must allow a minimum of salt passage, have a low tendency to foul, be chemically inert and have a long operating life.

In spite of these very challenging criteria, the objectives have been met. There are at least three families of synthetic membrane made from cross-linked polymer which have been successfully commercialized in North America. The three are cellulose acetate (CA), polyamide and polysulfone.

One of the most difficult problems to overcome in the development of the membrane was to configure a thin membrane that could withstand high operating pressures. Two configurations that succeeded were the hollow fibre and the thin film composite. In the case of the hollow fibre the walls of the fibre are composed of the membrane material itself while in the case of the thin film composite, the membrane is a very thin layer coated upon a porous support structure. In the early days of development, the hollow fibre was the predominant form of membrane used. It was put into bundles and enclosed in cylindrical pressure vessels of from 2" - 8". However, the most significant recent developments in membrane application technology have been with the spiral wound membrane. The balance of this paper will concentrate on practical application of the spiral wound, CA and TFC membranes.

The TFC membrane is cast in sheets and wound in spiral fashion with spacers into a cylindrical form (see diagram). The flow of water is along the z-axis while the passage of permeate is perpendicular to the surface along the x-y axis. This is conveniently referred to as crossflow filtration. The spiral wound membrane is manufactured in different standard sizes but is generally 40" long and 8" in diameter for municipal and industrial installations. The membranes are installed in series of 2 - 6 in pressure vessels and the pressure vessels are arranged in parallel and in series to provide the most favourable performance. The engineered configuration is referred to as the array.

The array of the RO system is critical to its performance. Each membrane must have a minimum flow to prevent fouling and a maximum flow rate to prevent excessive pressure loss. Each individual membrane will recover 10 - 15% of the flow and pass on the remaining concentrated flow to the next membrane until a total recovery of 70 - 80% is obtained across the system. The permeate is collected from each membrane while the process flow becomes more concentrated and of lower volume as it proceeds through the system.

As you can imagine, the water is passing through very restrictive passages under high pressure and becomes more concentrated in dissolved and suspended matter. This can create an environment conducive to scaling and fouling. Accordingly, the quality of water fed to the RO is extremely important. One of the single largest factors in the failure of membrane systems in their early years of introduction was inattention to pretreatment.

The two most important quality characteristics of feedwater to an RO are the SILT DENSITY INDEX (SDI) and the Langlier scaling index. The SDI is an arbitrary number that is determined by passing a sample of water through a 0.45 micron filter and measuring the drop in filtration rate over time. The formula used is:

$$\mathrm{SDI} = \frac{1 - \frac{Ti}{Tr}\ (100)}{T}$$

T = Total test time
Ti = Time to pass initial sample
Tr = Time to pass sample at time T

Generally, the silt density index of a well water is low enough that no treatment is required for SDI reduction. Surface waters on the other hand, often have very high SDI's necessitating careful design of a pretreatment program. Treatment to reduce SDI includes clarification, filtration, softening and pH adjustment. Scale control is easily obtained with acid feed, hardness reduction or chemical treatment with a scale inhibitor.

In addition to control of scaling and SDI, the membranes themselves are sensitive to certain chemical characteristics of the feedwater. The cellulose acetate membrane is subject to bacterial attack and requires a continuous chlorine residual. The TFC membrane is bacterial-resistant but subject to oxidative degradation and therefore must have an unchlorinated or dechlorinated feedwater. In all cases the water must be free of suspended material with a turbidity less than 1 NTU. Careful consideration must be given to the presence of iron. This should be kept below 0.1mg/L and if expected to be a problem a good iron dispersant should be fed before the RO. Silica by itself is tolerable to levels up to 30 - 50 mg/L, but in the presence of iron will cause membrane fouling if not treated appropriately.

Perhaps this all seems very confusing, but in reality RO pretreatment is merely the selection of common water treatment processes by experienced water engineers. The following summary is a quick check list of the parameters mentioned:

CHARACTERISTIC	CA	TFC
TURBIDITY	<1.0mg/L	<1.0mg/L
SDI	<5	<5
pH	5.0-6.5	2-11
CHLORINE	RES	NONE
IRON	<0.1mg/L	<0.1mg/L
SILICA	<50mg/L	<50mg/L

Perhaps the most interesting feature of reverse osmosis is the thoroughness with which it removes all dissolved constituents of water including organics, inorganics and colloidal materials. The quality of the permeate is comparable to demineralized water, but with additionally removed organics and micro-organisms such as bacteria and viruses.

To give you some idea of this, I have listed some of the usual water components and the typical removal.

Calcium	98%	Nitrate	98%
Magnesium	98%	Phosphate	98%
Sodium	96%	Bacteria	>99%
Potassium	96%	TOC	>80%
Carbonate	96%	Trace Metals	>90%
Chloride	96%	Colour	>90%
Sulphate	98%	Dissolved Gases	Nil

From the list of items removed, it soon becomes evident that there are many applications for RO in both municipal and industrial use. Certainly the most common current use of RO is in the reduction of TDS from well water supplies. In addition though it is also frequently used to remove one specific ion that exceeds the desired limit such as fluoride, sodium or phosphate. Or RO can remove a trace metal such as copper or lead.

An obvious application for RO is to remove organics in the form of colour from water. Here it offers some distinct advantages over the conventional clarification process. Because a coloured water is often low in TDS, alkalinity and turbidity, it is difficult to flocculate.

Plant operators must resort to exotic combinations of treatment chemicals using alum, sodium aluminate, ozone, lime, polymers and a multitude of metallic salts to obtain colour removal. Even with the colour removed, the operator is then faced with the problem of disposal of the chemical sludge produced from this process. This whole procedure can be eliminated through the use of reverse osmosis. Pilot plants operated by Zenon Environmental have demonstrated that complete colour removal can be obtained with no fouling of the membranes. Consistent quality of results and ease of operation highlighted these studies.

Increasing awareness of the presence of less obvious trace organics in our waters, even in ground water supplies has brought RO into consideration for even broader application. Contamination of our surface and ground water supplies from agricultural chemicals, landfill sites, and chemical dumps will necessitate increased use of RO to ensure the supply of safe water to the members of our Canadian communities.

A final use for RO that is particularly applicable here in the foothills of the Rockies is in the removal of microcontaminants such as the Giardia Protozoan. Studies reported on in the AWWA Journal have demonstrated that Giardia in the cyst stage are effectively removed in effectively operated media filters. However, it is known that the operation of good flocculation on cold, low solids water is not an easy task. I predict that there will be an increased use of RO for bacterial control in municipal water in the future.

Since the reverse osmosis process requires strict feedwater quality, pretreatment chemicals are often used. These include sulphuric acid to lower the pH, sodium bisulphite to remove residual chlorine and scale inhibitors and dispersants such as phosphates and polyacrylates to prevent scaling on the membrane surface. These chemicals can be used with little impact on the permeate water quality since they are all retained in the concentrate. Chemicals should, however, be used sparingly since they eventually require disposal as a component of the brine.

RO permeate is corrosive. With over 96% of the TDS removed the water is aggressive and will attack mild steel or cast iron pipe. There are several ways to eliminate this problem. If the RO is being used to only lower a constituent such as sodium or nitrate, then only a portion of the flow needs to be treated. The combination of the untreated portion will provide sufficient mineral content to reduce the corrosivity. If, however, the constituent must be completely removed as in the case of a pesticide or a bacteria, then all the water must pass through the membrane and post treatment with caustic, soda ash, chemical inhibitor or other additive will be required.

Membrane manufacturers have noted the need for a membrane that will remove all organics and microorganisms and provide only partial removal of TDS. Membranes capable of doing this have been developed and are currently being commercialized. They have been coined "loose RO" membranes and will bring an exciting new dimension to the water treatment field.

I think I have spoken enough about the theory and application of RO, now lets turn to the practical side of the business/operations. I recently had the pleasure of touring several RO installation sites with a prospective user of a large RO system. This man has extensive experience in the operation of a large clarification, filtration and ion exchange plant. After visiting three locations, he observed that he now knew why RO wasn't used more -- it was too damn simple!

The fact of the matter is that with the problems of inadequate pretreatment behind us, Reverse Osmosis today is an extremely easy to operate and reliable process. There are several key elements to the successful selection and operation of an RO system.

- A WELL-ENGINEERED SYSTEM
- PROPER START-UP
- OPERATOR TRAINING
- FLUSHING/CLEANING REGIMEN
- OBSERVATION AND DOCUMENTATION

With these five basic steps, there is no reason today for an RO system to fail to meet the anticipated performance level.

The proper design of a reverse osmosis system must include the selection of the correct membrane and the proper pretreatment for the membrane. It must include the proper membrane array to provide adequate flow rate but not excessive. The optimum operating pressure and recovery rate should be chosen with a view to obtaining the best pump efficiency, membrane utilization and length of service of the membrane. All of these design features should be provided by the supplier of the system. It is apparent from the number of significant criteria that your supplier should be carefully chosen.

If there is going to be an operational problem with the RO, it will probably be evident at the time of start-up or shortly after. Further, if there is an operational error it will most likely occur during or shortly after start-up. Serious damage and operator frustration can be avoided by using the start-up and training services of the supplier. The most common problems experienced on start-up are due to very common electrical and plumbing errors. The use of wrong voltage blowing the control board, valves closed and causing a pump to deadhead, foreign articles in the piping fouling control valves. I will elaborate on some specific problems found in operating systems later on.

Consistent performance of an RO system requires a simple but regular cleaning program for the membranes and a regular recording of the operating data. All municipal operators are familiar with the procedure for carrying out these duties. The cleaning procedure is generally done once per month, but many systems are cleaned only every quarter or less. The cleaning process itself should take about 2 to 3 hours. The steps involved are:

1. Fill cleaning tank with permeate and add cleaning agent.
2. Open reject valve fully. Ensure all hoses and valving are properly positioned.

3. Recirculate cleaning solution for 30 minutes.
4. Flush system and return to service.
5. Record operating data before and after cleaning.

Proper documentation of operating data is invaluable in tracking the condition of the membranes. It enables use of a good preventative maintenance program and ensures maximum utilization of the membranes, the most expensive operating cost of the RO system.

The three major operating costs of an RO system are the power consumption, the membrane replacement and reject water. Chemical pretreatment and cleaning costs are not significant. It is not within the scope of this paper to include a detailed cost evaluation or comparison with conventional treatment. There are too many variables in each circumstance to attempt any general guidelines. However to provide some base line data on RO, power consumption is about 20¢-25¢/1000 gallons. While the replacement cost of membranes is in the range of 23¢/1000 gallons. The capital cost of RO systems in excess of 200 gpm is about $1,000 per gpm of capacity or less. A system of 5,000 - 10,000 GPD would cost $15,000 - $25,000. Other major features of Reverse Osmosis systems are the ease of installation and low space requirements. This significantly reduces overall installation cost.

A survey of operating problems with RO systems in 1984 was recently published in AWWA JOURNAL. There did not appear to be any predominant or persistent problems that reoccurred. The problems and recommendations mentioned were:

More regular membrane flushing
Iron bacteria fouling
Membrane fouling
Acid feed system deterioration
High silt density index
Increase test and sampling points
Improved connections for flushing

These are rather common operational difficulties and ones which can be readily attended to by a regular service department.

In summary, I would like to say that RO has come a long way in the last several years to the point where it is now a reliable, established technology that is becoming increasingly competitive as a municipal treatment process. You will begin to see RO used more frequently in both municipal and industrial plants and you can be assured that a properly designed and installed system will provide you with a high quality water supply from a system that is both easy to operate and reliable.

CHEMICAL FREE WATER TREATMENT

Poul Wesch
WSH Laboratories Ltd.

Water treatment in Alberta is very much a fact of our daily life. Only in a few places do we have a raw water quality which needs no further treatment, and the rest of us encounter a variety of impurities that must be dealt with to produce good potable water.

Most small scale water treatment systems draw from our subsurface acquifier which contains dissolved minerals, hardness and a number of other solids. Larger municipal systems and some areas in the northern portion of our province draw from our surface water which can have the same dissolved matters, suspended solids in addition to organically bound pollutants.

The traditionally known methods all utilize chemicals and these methods in various stages and combinations are: pre-disinfection, oxidization, flocculation, sedimentation, filtration and post-disinfection. Most of the water we use and drink has been in contact with chemicals like potassium permanganate, aluminium sulphate and chlorine. For many years chemically treated water has been acceptable as well as being the only known treatment method and the only results we have seen from advanced technology and "space-age" technology is more sophisticated means of handling and applying these harsh chemicals.

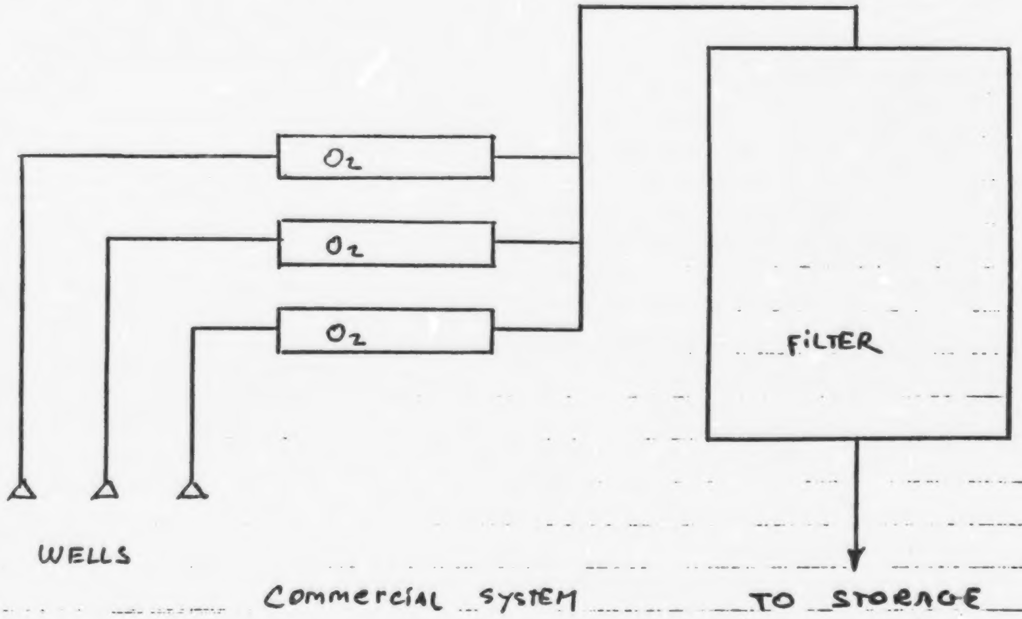
In our laboratory we have now for some years researched traditional and new water treatment methods, and we have found that a new chemical free approach to water treatment is not only possible but it is viable, it is very simple, it is very economical and it works. Test results from hundreds of domestic and some commercial installations are not just better than the average expectation but in almost all installations better than results obtained from traditional types of systems. These results are all from PHASE 1 of our three phase research program which is designed to deal with all areas of water treatment.

PHASE 1) Subsurface waters
PHASE 2) Surface waters
PHASE 3) Wastewaters

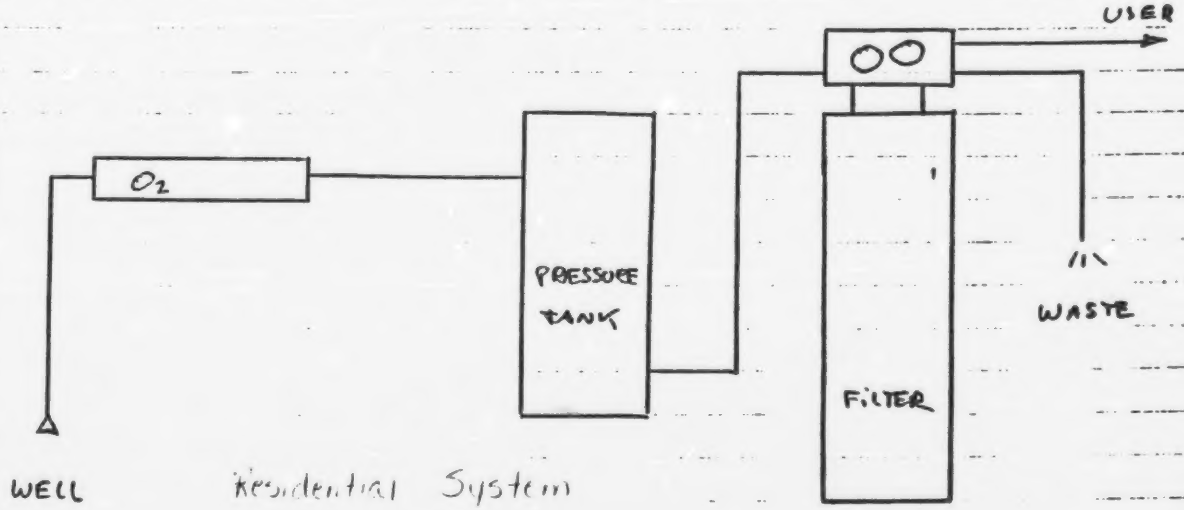
The common denominator in all areas of treatment is the use of oxygen at different levels varying from the natural state of oxygen found in the air we breath, to the artificially generated state of oxygen found in ozone. Oxygen is a gift to us: a Free-Bee and it is used in our nature to break down waste products. Consider a burning branch or a rusting bar of iron. Nature's way is clean and void of harmful by-products and nature's way is available to us for the taking if we choose to utilize it.

Aeration, however, is nothing new and we use aeration systems quite commonly in water treatment. What we have simply accomplished is to take areation a step further; vastly improve the contact method and we can now classify the concept as oxidation. Here is how it works.

Air is drawn in (or injected) into the water supply line then contacted, dissolved, and perfectly mixed in a specially designed accelerator mixing valve. The amount of air is carefully regulated and monitored through an air flow meter. However, the contact method in the accelerator mixer is the vital function of this system. In the mixer, water is accelerated violently into a rotary motion during which extreme pressure is built up against its outside wall. This pressure breaks down the entrapped air into minute particles. The air is dissolved in water, complete contact and mix is obtained and the oxidation is complete when the water leaves the unit.



Commercial system



Residential System

We have measured an increase of dissolved oxygen in water from 8 ppm under static conditions up to 32 ppm after injection through the accelerator. The initial studies on the accelerator were conducted with oxygen injection in sewage effluent to decrease the bi-chemical oxygen demand (BOD), but when it comes to oxidizing dissolved minerals in well waters, all we need is the amount of oxygen available in the air. We don't know yet the maximum amounts that the system will treat since we are limited by the water that is available around us. So far we have effectively treated the following to well within the limits of Canadian Drinking Water Standards.

Iron = 22 mg/L to <0.05 mg/L
H_2S = 2.5 mg/L to below detection
Manganese = 1.0 mg/L reduced to 0.02 mg/L

These are actual field results obtained by users of the system. Our highest iron contamination to date is 32 mg/L and it has not caused any difficulties. If anyone in this group is familiar with a water source with higher contamination, we would like to know as this might help us to find the upper limit to the system.

Types of filter media have been successfully used on this type of water: Birm or manganese greensand. The Birm media is the most ideally suited as this media type acts as a catalyst between the dissolved oxygen and minerals. It is lightweight and provides higher filter flow rates yet requires very low backwash flow rates being lightweight and easily expandable during backwash. The oxidized particles wash out easily and leave the birm media completely clean as was it new. Birm should not be used on other oxidization methods as they produce a sticky particular matter which inactivates the birm media.

Manganese Greensand filter beds have been performing well on the air oxidation method and is recommended in situations where the air oxidizer is adapted to an existing filter system, which may have previously utilized potassium permanganate. The filter media should be inspected and if necessary rejuvenated or cleaned up after lengthy use of chemicals.

The difference in the oxidized particles derived from the two methods (oxygen and potassium) is significant. Potassium permanganate forms with iron an iron hydroxide which is a sticky soft substance that can bond the media and develop stratified flows through the media whereas the oxygen method resuits in a dry powdery matter (iron oxide) that easily flushes out during backwash.

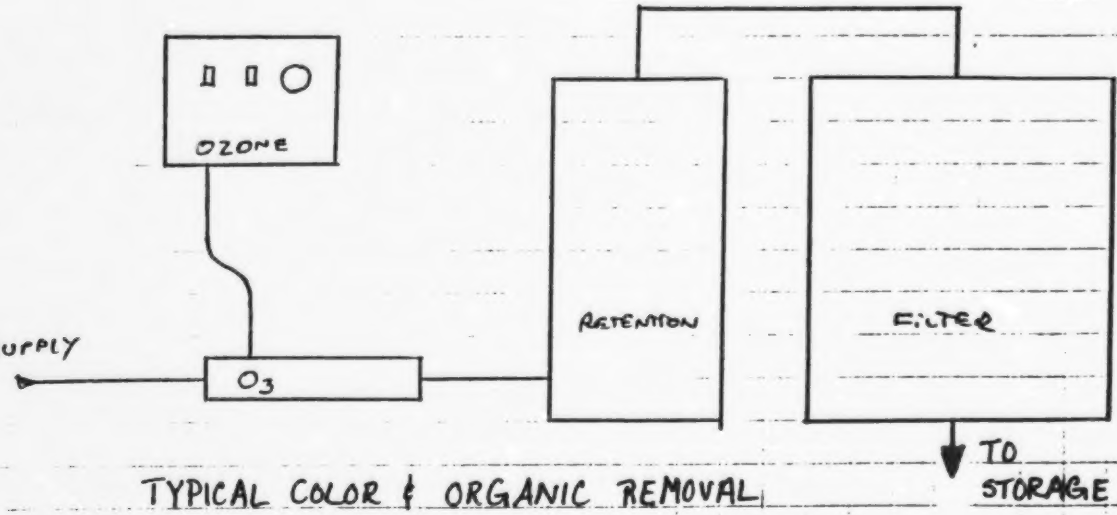
The amount of air required in this air oxidizing process is very limited. All of the injected air will dissolve in water during the entire filtration process and the air will stay in the solution until the water is no longer under pressure. A pleasant side effect is that this treatment method produces crystal clear water which due to the use of air has a very pleasant, fresh taste. In summary, here are a few facts:

1. Effectively removes iron, manganese and sulphur gas (rotten egg smell).
2. Uses no chemicals.
3. Requires no maintenance.
4. Produces clear, clean, and naturally well tasting water.
5. It is cheap!

The method of contacting and mixing has been a process development that has given us a lot of experience in the field of water treatment. At the same time this process has opened new fields for research and we anticipate having to learn a lot more. Here are some areas that in this process may see new treatment methods:

1. Aeration of storage reservoirs and dugouts with raw and treated water.
2. Treatment of organics or organically bound dissolved minerals with oxygen or ozone.
3. Use of air or oxygen in sewage effluent.
4. Disinfection and treatment with ozone.

These are areas that we currently have test pilots on. The results are promising and some final system designs are already available.



TYPICAL COLOR & ORGANIC REMOVAL

As a contactor the accelerator mixer valve has already proven itself far more effective than any known in-line mixing concept. When used with injection of flocculating agents we have dramatically reduced the required floc-retention time. With mixed emotions we have found that the oxidizing powers of chlorine have increased to new levels. However, in the context of a chemical free world of water treatment this is still an acceptable finding as the chlorine dosage in this method is only a fraction of what traditional methods would require.

It is refreshing that water treatment can be approached successfully with new angles. Our sources of fresh water are very precious, although they are deteriorating in quality and quantity. We must treat Mother Nature's presents with care and utilize natural means of purification. Our by-products and our waste products should be clean and void of contaminants or chemicals to secure usable water resources for our children and grandchildren.

We now have facilities in our laboratory to accommodate small groups of people for our water treatment seminar. This is a no cost, low key seminar designed to provide the group with a specialized knowledge on water treatment and for us in the discussion to obtain information on localized water problems in our province. We also invite you to send us a water sample for analysis and treatment recommendation. It will help if you send a brief description of your current treatment facility with the sample.

This advanced water treatment technology opens up new avenues for those of you who are faced with upgrading, improving, or rebuilding your facility. We hope it will assist you to obtain compact design, efficiency, economy, and improved water quality. If some questions come up, you are always welcome to give us a call. If we can help you with some sound advice, we are only pleased to do so.

THE FLORA AND FAUNA OF WASTE TREATMENT PONDS

Jim Gratz
Town of Strathmore

I don't know about you, but what happens in a waste treatment pond was a never ending source of mystery to me. The volume of misinformation that came my way was no help either. You've run into it yourself, "Well, I know what the trouble with your pond is. It ain't workin'. What you need is a sheep's stomachs. Ya, get yourself a load of sheep's stomachs. Toss 'em in the lagoon and yer troubles are over." Bet you've heard that a hundred times, right? Well, I did and I'm here to tell you it ain't so.

Seriously, in any discussion of what you expect from your treatment process, the first step is to determine your goals. What are your goals for your waste water stabilization process? Mine are:

1. To provide a treatment process capable of sufficient suspended solids, bacteria, and nutrient removal to provide a treated effluent that will not, when released to the receiving water, significantly increase the pollution factor in that receiving body.
2. To provide a treatment process that will not produce an odor problem to residents down wind of that process.
3. To provide an effluent capable of meeting the Alberta Environment guidelines for treated waste effluent.

The bottom line is, how well you obtain your goals depends on how well you maintain your process and how well you know the flora and fauna and plants and animals that provide that process. A sound basic knowledge of what you are working with, their likes and dislikes, will make all the difference in the world to what you achieve as an end product.

Before we have any discussion of plants and animals, we should deal with their habitats. Habitat is a major factor for any plant or animal. It effects the way they live and how productively they live. In this case the habitat is the wastewater stabilization pond; lagoon as some call it. No matter how simple or complex the plant or animal involved, its reaction to its habitat will be either negative or positive. Based on this reaction, it will perform more or less effectively. It is, therefore, our job to ensure that the habitat is acceptable to those who live there.

To do this we must understand the nature of various habitats. Since there are three types of organisms - aerobic, anaerobic, and facultative; there must be three types of habitats for them to live in.

The term aerobic means "with air". These ponds are ideally very shallow, approximately three to four feet deep, and have abundant natural or mechanical aeration to provide plenty of oxygen to the organisms that live there.

Anaerobic means, "without air". The sorts of plant and animal life that live here do not want oxygen handed to them. They want to work for it. These ponds are much deeper than aerobic and smaller in area to prevent excessive aeration.

The last type of pond is a combination of the two previous ones. Bacteria that live here are able to function with or without oxygen content in the water moving freely from the aerobic to anaerobic zones and back. This is the facultative pond named for its inhabitants.

Many factors are involved in the efficient operation of stabilization ponds. Here are just a few to give you an idea of what is required to make them function well. Sunlight - in all cases light is required to create warmth because heat makes the bugs work hard. The temperature of liquid wastes determines, to a great extent, the speed of bacterial action and thus the quality of the process. It is important that organic and hydraulic loading be stable and at proper levels so as not to give the organisms more work that they can handle. As in any work place, pond depth and size is important to ensure proper working conditions for the workers. Mineral content of the water supply is important because it may create a hazard to pond and organism condition.

We've looked at the living quarters, now let's have a look at the food. All dissolved or suspended matter in wastewater may be put under one of two classifications - organic or inorganic. A major portion of organic solids are volatile and/or biodegradable. Volatile means organic matter that is readily evaporated or changed to gases at relatively low temperatures. Biodegradable means organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odors. A primary objective of wastewater treatment is the removal of organic solids. That is what our little friends do. They reduce volatile and biodegradable matter in wastewater to gases and sediment. This process is called "bioconversion" and is what is known in the business as a biochemical reaction.

Now let's see what makes up the menu for our organisms. All matter is comprised of one or more elements. All organic matter is made up of groups of elements grouped to the element carbon. "Natural" organic compounds are the products of living organisms, either plant or animal. "Synthetic" organics are manufactured compounds. Usually, only trace amounts of synthetic organics are found in domestic wastewaters.

Natural organics have been divided into several classes. The classes most abundant in domestic wastewaters are fats, carbohydrates, and proteins. Fats consist of the elements carbon (C), hydrogen (H), and oxygen (O). Carbohydrates also consist of various combinations of carbon, hydrogen, and oxygen. Proteins, however, are more complex and contain not only carbon, hydrogen, and oxygen, but also nitrogen (N), sulphur (S), phosphorus (P), and sometimes iron.

Now that we know about the organism types, habitats, and menus, let's get to the organisms. We'll start with bacteria. Bacteria are primitive, single-celled living organisms, microscopic in size, most of which use organic matter for food and produce waste products as a result of their life processes.

As part of their digestive process, bacteria produce substances called enzymes. Enzymes form a solution around the bacteria that produce them. Bacteria live in these solutions, absorbing food produced by them. Enzymes liquify or predigest specific chemical compounds. Certain enzymes liquify fats, others digest proteins, and still others breakdown carbohydrates. Bacteria then absorb the broken down substances from this enzyme solution in which they are growing.

Bacteria normally reproduce by splitting into two bacteria. They eat like crazy until they reach a stage of development adequate for reproduction and then they simply do it. Given proper conditions, plenty of food and proper environmental conditions, the bacterial population of our pond could double in a matter of minutes. It is this eat, grow and reproduce cycle that accounts for the digestion of the sludge in your treatment ponds.

Now we go to the mini-flora of stabilization ponds. Algae is the most readily identifiable of these. Phytoplanktonic algae are tiny, single celled plants that grow abundantly in stabilization ponds. They create the most striking visual feature of a pond through the green coloration they impart to the water. These minute plants are found in almost every treatment pond.

Algae contain chlorophyll used in conjunction with sunlight to eat. They multiply by simple cell division much as bacteria. Oxygen resulting from algal photosynthesis is available in quantities exceeding the respiratory needs of the algae population and other organisms during daylight hours in facultative stabilization ponds. Since algae are plants they only produce significantly during daylight hours when plenty of light and warmth is available.

A symbiotic relationship exists between algae and the air breathing bacteria and insects in the pond. Algae produce vast amounts of oxygen and in turn the bacteria and other animals use oxygen. Through their respiratory function, these bacteria and insects, produce carbon dioxide, a compound necessary for algal photosynthesis. In this manner nature assures itself that the process of digestion will continue on.

Were the aeration of your secondary stabilization ponds left to surface reaeration by wind action, your ponds would soon die, as this method cannot produce enough oxygen. These tiny plants are, therefore, essential to the effective operation of your pond system.

In addition to the valuable oxygen producing function, algae reduce the amount of nutrients in your wastewater. Compounds such as nitrates, nitrites and ammonia are the gourmet delights of algae. Large populations of algae in a stabilization pond are able, over the course of a summer, to significantly reduce the amount of these substances, thus improving the quality of your final product.

Insects are also abundant residents of your ponds. Anyone who has been around a pond system for any length of time will attest to this. Insects are part of the natural control system that not only remove organic detritus - the heavy course mixture of organic material carried in waste water - but also control the volume of bacteria and algae present.

In a healthy system, an abundant supply of higher animal life must be present. There are many types of higher animal forms present in stabilization ponds. Some are more or less effective in actual water quality improvement, but there are few that make a big difference.

Larvae and Midge flies are very abundant in most ponds. The larvae are bright red, due to a high hemoglobin content in their blood. This allows them to live in waters having low oxygen content. You have probably all seen around the edge of your secondary pond, clouds of red stuff. That is larvae.

Sometimes known as blood worms, larvae live by building a tubular structure which is open on both ends. They construct it from debris in pond water. A net is constructed and affixed to one end of the tube. The net is constructed from a liquid substance excreted by the larvae. Through the use of undulating body movements, a flow of water is produced through the tube. Particulate matter is trapped in the net and larvae feed on the entrapped particles. Midge fly larvae abound in the shallow edge area of ponds.

In any pond insect population, water boatmen make up a large sector of that population. They feed on organic detritus and other suspended matter. The eggs of boatmen are attached to sticks, weed stems and other solid objects in pond bottoms. Should this substrata be missing in your ponds, then there will probably be a lack of boatmen. They must have this material to reproduce.

As in any ecosystem, there are predatory animals. A number of species of predatory insects may be present in a stabilization pond. Their prey consists of other insects and crustaceans living in the pond. Probably the most common predator is the water tiger or diving beetle.

Given proper conditions, mostly present in poorly maintained ponds, mosquitoes abound. Pools of stagnant water along the edges are prime breeding areas for mosquitoes. Build up of sludge deposits and overhanging bank vegetation also aid in reproduction. Mosquitoes are virtually non-existant in properly maintained pond systems.

Rotifers, capepods, and cladocera are desirable inhabitants of stabilization pond systems as they contribute to energy dissipation. This dissipation occurs through biological recycling by their consumption of algae, protozoa, bacteria, and other suspended organic matter.

Daphnia are excellent at clarifying pond waters. Light penetration of it is enhanced, through this clarification, thus permitting algae reproduction at greater depths than normally would be the case. In addition to that benefit, algae reduction due to cropping by Daphnia, likely stimulates increased algae growth which, in turn, makes for greater nutrient removal.

Carbon dioxide, nitrate and soluble organic-bound iron become available for new algae cell production. In ponds with elevated pH levels, Daphnia are less abundant or non-existant. Algae photosynthesis results in production of dissociated ammonia compounds which reduce the population.

Rotifers and cladocera are susceptible to pH factors the same as Daphnia. It has been noted that they are most abundant in ponds whose water has a pH between seven and eight. High pH also appears to be adverse to snails and seed shrimps. Some species of capepods are more tolerant of high pH levels. These are all animals who contribute a valuable service in pond ecology.

Many other higher forms of life contribute, more or less, to the welfare of your pond's worms, leaches and scuds. They feed on organic detritus reducing your treated suspended solids. Scuds have only been observed in those ponds having stony bottoms or those whose berms are rip rapped with rock. Nematodes, tiny thread-like worms, feed upon organic solids and may become quite abundant in overloaded ponds.

This has been a quick summary of the plant and animal life that make up the treatment process in your pond. As mentioned earlier how well these workers work to clean your waste water, depends on how well you treat them. It is important that you learn about them, their likes and dislikes, and strive to please them.